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PALEONTOLOGY

JOURNAL OF PALEONTOLOGY

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of Michigan, Ann Arbor, Michigan.
For The Society of Economic Paleontologists and Mineralogists: M. L. THOMPSON, State Geological Survey, Urbana, Illinois

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VOLUME 31 JULY, 1957 NUMBER 4

MISSISSIPPIAN ENDOTHYROID FORAMINIFERA FROM THE CORDILLERAN GEOSYNCLINE

EDWARD J. ZELLER
University of Kansas, Lawrence

ABSTRACT—Through the use of endothyroid Foraminifera it has been possible to recognize four widespread faunal zones in the Mississippian rocks of the western United States. The faunal succession of the endothyroids and the lateral extent of the four faunal zones were determined by thin-section studies of samples from twelve measured sections distributed along the Cordilleran Trough from Arizona to Montana.

The lowermost zone is based upon the presence of a new genus of endothyroid foraminifers and is considered to be Kinderhookian in age. Rocks containing this fauna are overlain in most areas by those with an especially distinctive new species of *Plectogyra*, most probably Osagian in age. Both of these zones are typically developed in the Madison limestone of Utah, western Wyoming, and Montana.

The two upper endothyroid faunal zones are each characterized by a new species of the genus *Endothyra*. The lower of these zones is Meramecian in age and all of the forms present show close similarity to those in the Salem limestone of the Mississippi Valley area. The species which distinguishes the upper faunal zone is similar to a form in the Ste. Genevieve, but the associated endothyroids seem to have more affinities to the fauna from the type Chesteran. Rocks containing one or both of the upper faunal zones have been found in the Paradise, Escabrosa, and Redwall formations in Arizona and in the Brazer and several thin and unnamed limestones in Utah.

INTRODUCTION

THIS investigation was undertaken in an effort to extend the usefulness of endothyroid foraminifers in the correlation of the Mississippian rocks of North America. The general faunal succession of the midcontinent had been studied by E. Zeller (1951) and the details of the Chesteran endothyroid faunas were reported by D. Zeller (1953). Both of these studies indicate that within the midcontinent, endothyroid faunas are highly diverse vertically and widespread laterally. Since the Mississippian limestones of the Cordilleran Region rarely carry good assemblages of macrofossils which can be used for correlation, it was thought that the endothyroids might be of especial value for this purpose in the thick limestone sections which frequently are without distinctive lithologic breaks.

Twelve Mississippian sections were measured and sampled. These sections were chosen along the Cordilleran Trough from Montana to Arizona. Thin-section studies of the limestone units provided enough detailed information to permit the delineation of the faunal succession of the endothyroid foraminifers. After several sections had been examined it became apparent that certain species could be used to mark specific zones.

The completed study enlarged the areal extent of these zones and provided the basis for the faunal zonation proposed here.

Special thanks are due Dr. M. L. Thompson for his advice and aid in completing this study. Measurement of sections and collection of samples was made possible through the generous cooperation of the Phillips Petroleum Company. I wish to extend my specific appreciation to Alex W. McCoy III and J. T. Donovan and to the remainder of the Phillips staff of field geologists without whose cooperation this study would have been greatly restricted. Thanks are also extended to my wife, Dr. Doris E. Nodine Zeller, who frequently accompanied me in the field, aided in the preparation of the plates and manuscript and drafted the sections included herein.

GENERAL STRATIGRAPHIC RELATIONSHIPS

It has long been known that the Cordilleran Region shows exceedingly complex stratigraphic relationships, especially in the Upper Paleozoic sediments. Much of the tectonic activity which is reflected by the rapid local variations in facies in the Pennsylvanian and Permian rocks had its initiation in Mississippian times. In some of the more disturbed areas, especially in the Great Basin, lithologic correlations are not trustworthy and unconformities complicate the stratigraphy to such an extent that paleontologic methods are required to get a truly accurate picture of Mississippian tectonic history.

The endothyroid foraminifers are of special value in these stratigraphic studies because of their relative abundance in Mississippian limestones. They are frequently the only fossils present and they are commonly well-preserved. Individual genera are often widespread. Correlations within the Cordilleran Region are possible throughout the entire section with the aid of endothyroid Foraminifera, but only the Middle and Upper Mississippian rocks contain faunas which are directly comparable to those presently known from the Mississippi Valley type area. Further study of the endothyroid faunas of the Mississippian type section might yield a better basis for comparison with those of the Cordilleran Trough. It is hoped that this study will be undertaken at some future time.

Endothyroid foraminifers are present throughout many of the Mississippian sections which were studied, although in some instances they were limited to comparatively few beds. Endothyroids were not found in the lowermost hundred feet of any of the thicker Mississippian sections studied and none has been obtained from the Devonian rocks of the area. The diversification and advanced evolutionary stage of the forms which are present in the lowermost endothyroid zones of the Mississippian clearly indicate that a more intensive search of Upper Devonian rocks is needed to complete the knowledge of their ancestry.

The extensive endothyroid faunas which are present in the Kinderhookian and Osagian rocks of the northern portion of the Cordilleran Trough were not found in any of the sections south of central Utah. The reason for the absence of foraminifers in the lower limestones of these sections seems to be primarily related to the conditions of sedimentation and extensive secondary dolomitization.

Meremecian rocks are widespread and are certainly identified in all of the sections south of the Wyoming-Utah line with the exception of the Nopah section in California. Forms present in these rocks compare very closely with those in the type Meremecian, and correlations with rocks outside the region are most definite in this portion of the section. Chesteran rocks are present in hte Cordilleran area, and they attain considerable thickness but their geographic distribution is much restricted. The Chesteran faunas seem to be divided into two distinct and different assemblages. One of these is found in a single section in extreme southeastern Arizona and shows a marked similarity to the midcontinent Chesteran faunas described by D. Zeller. The other assemblage was encountered in several Chesteran sections in Utah, and the endothyroids in it appear to be more closely related to the European and North African upper Viséan assemblages examined by D. Zeller.

COLLECTION OF SAMPLES

Whenever possible the complete Mississippian section ranging from rocks of known Devonian age to rocks of definite Pennsylvanian age was measured and sampled in a single area. Samples were collected from

each change in lithology encountered in the carbonate sediments. Collections were often made from the bottom, middle, and top of massive units of uniform lithology. Some of the stratigraphic sections studied contained abundant and well-preserved endothyroid foraminifers in almost every bed, whereas other sections contained only a single zone in which the shells were sufficiently well-preserved to be identifiable. Adequate sampling throughout the section is necessary in order to avoid the possibility of missing limited zones in which the foraminifers may occur and also to permit the accurate stratigraphic location of critical changes in the endothyroid fauna.

Endothyroids rarely can be observed in samples in the field and only experience will provide the criteria for selection of specimens which are most likely to contain these foraminifers. In general, they are most common in dense, fine-grained, or oolitic limestones. They are normally associated with a coral-brachiopod assemblage and are only rarely found in coarsely detrital limestones or in association with abundant crinoid remains. Silty limestones carrying a molluscan fauna are least likely to contain endothyroids.

All of the endothyroid foraminifers examined and illustrated in this work have been obtained through the preparation of thin-sections of limestone. A few shale samples from the Cordilleran Region were washed, but always with disappointing results. Specimens have been observed occasionally in chert, but they are usually replaced in such a way that wall structure cannot be studied. Forms preserved in chert present special problems in photography and generally lend themselves to study in polished surfaces rather than in thin-sections.

SPECIAL THIN-SECTIONING TECHNIQUE

While the technique for study of the endothyroid foraminifers was originally developed from methods used in sectioning the smaller fusulinids, such changes have been necessary that it is felt a general account of the method is in order. The lithologic character of the rock under examination often requires variations in the basic methods of study. The use of polished surfaces for the preliminary examination to determine the presence or absence of endothyroid shells is almost entirely satisfactory in some rocks, whereas, in others, polished surfaces fail to show the presence of the shells. Polished surfaces of rocks from the Cordilleran Region frequently do not reveal the presence of endothyroid foraminifers even though they are very abundant.

The small size of endothyroid foraminifers, together with the rarity of free shells, made necessary the development of a two-stage thin-sectioning technique. Random thin-sectioning of the limestone samples is usually satisfactory for determining which samples contain endothyroids and which do not, but it is too time consuming and too wasteful to be suitable for detailed work. Once a sample has been found to contain endothyroids it is processed as follows.

Samples to be thin-sectioned are oriented in such a manner that slices can be made parallel to the original bedding plane of the limestone. This procedure is usually followed because the sections which result are those which are most desirable for specific identification, i.e., the horizontal axial section in *Plectogyra* and the sagittal section of *Endothyra* and the discoidal fusulinids. The greatest number of specimens will be oriented in the desired plane if sections are cut parallel to the bedding because the foraminiferal shells, being discoidal, tended to settle on their sides on the bottom at the time of deposition.

The slices of limestone are polished on one side with very fine abrasive and usually examined to see if any shells are visible on the polished surface. Visible specimens are circled with lead pencil, and the slices are then mounted on large glass plates with thermoplastic cement. Standard lantern slide cover glasses are especially satisfactory for this purpose.

After cooling, the large slice is ground down in the conventional manner until it reaches a thinness which will permit enough light to pass through it to make examination with transmitted light practical. If the sample shows average transparency it will be possible to see the individual shells and to determine their orientation with fair accuracy by the time the thickness has been reduced to about a half millimeter. Specimens facing the glass can usually be recognized through the section and should be cir-

cled at the same time those facing the upper surface are being marked. After marking the individual shells in this manner the slide is heated and the thin slice of rock can be slipped away from the glass plate.

Specimens which have been marked are then clipped out of the rock slice by means of a parallel jaw wire cutter. The small fragments containing the specimens are then mounted individually on one by three inch standard microscope slides. Careful hand grinding will permit considerable change in the orientation of the plane of the final section. Many specimens will be found in which the plane of the preliminary section is nearly as it should be but the proloculus has not yet been reached. Specimens of this type can almost always be saved by remounting and hand grinding, whereas, they would be lost by random thin-sectioning techniques.

Besides the conservation of time, sample material, and individual specimens, the two-stage technique has a number of other advantages not obtained from random rock-section methods. Individual specimens can be treated separately and ground to the thinness which best shows their particular form and wall structure. Large numbers of poor slides containing only fragmentary specimens are never prepared.

Photography of individual specimens is greatly facilitated through the use of smaller numbers of better specimens ground to optimum thickness. Finally, the preparation of the large, thick, exploratory sections tends to give the worker a better over-all picture of the foraminiferal fauna in the bed under investigation. Most of the samples are sufficiently transparent to permit a view of the external character of the shells. Furthermore, examination of the large section provides a better average sample of the total fauna in terms of the abundance of the species under study than would be obtained from a collection of random sections. Large sections also permit special searches to be made for well-oriented specimens of diagnostic or rare species.

EVOLUTIONARY TRENDS AND GROUP CHARACTERISTICS

The endothyroids as a group deserve special attention for, on two counts, they mark the beginning of a new era in the evolu-

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EXPLANATION OF PLATE 75

Figures *1–13* ×150; figures *14–34* ×75

FIG. *1*—*Paramillerella* sp. Sagittal section showing chamber shape and aperture, Bed 14, Chiricahua Mountain section.

2,9—*Plectogyra* sp. Specimens showing secondary deposits. *2*, Bed 14; *9*, Bed 13; Chiricahua Mountain section.

3—*Paramillerella* sp. Axial section showing plectogyroid nature of the coil, Bed 14, Chiricahua Mountain section.

4—*Paramillerella tortula* D. Zeller. Sagittal section, Bed 14, Chiricahua Mountain section.

5,12—*Paramillerella tortula* D. Zeller. Axial sections showing slight rotation of the axial plane in the early volutions, Bed 13, Chiricahua Mountain section.

6,7,8,10,11—*Paramillerella tortula* D. Zeller. Sagittal sections; *6,7*, Bed 14; *8,10,11*, Bed 13, Chiricahua Mountain section.

13—*Paramillerella* sp. Oblique section, Bed 13, Chiricahua Mountain section.

14,18,19—*Endothyra symmetrica* E. J. Zeller, n. sp. Sagittal sections, Bed 9, Chiricahua Mountain section. *18* is the holotype.

15—*Plectogyra* sp. Vertical axial section, Bed 9, Chiricahua Mountain section.

16,17,22—*Endothyra* sp. Axial sections, Bed 9, Chiricahua Mountain section.

20,21—*Plectogyra irregularis* E. J. Zeller, n. sp. Horizontal axial sections showing secondary deposits, Bed 9, Chiricahua Mountain section.

23,24—*Plectogyra* sp. Horizontal axial sections, Base Bed 32, Havasu Canyon section.

25—*Endothyra spiroides* E. J. Zeller, n. sp. Sagittal section, Base Bed 32, Havasu Canyon section.

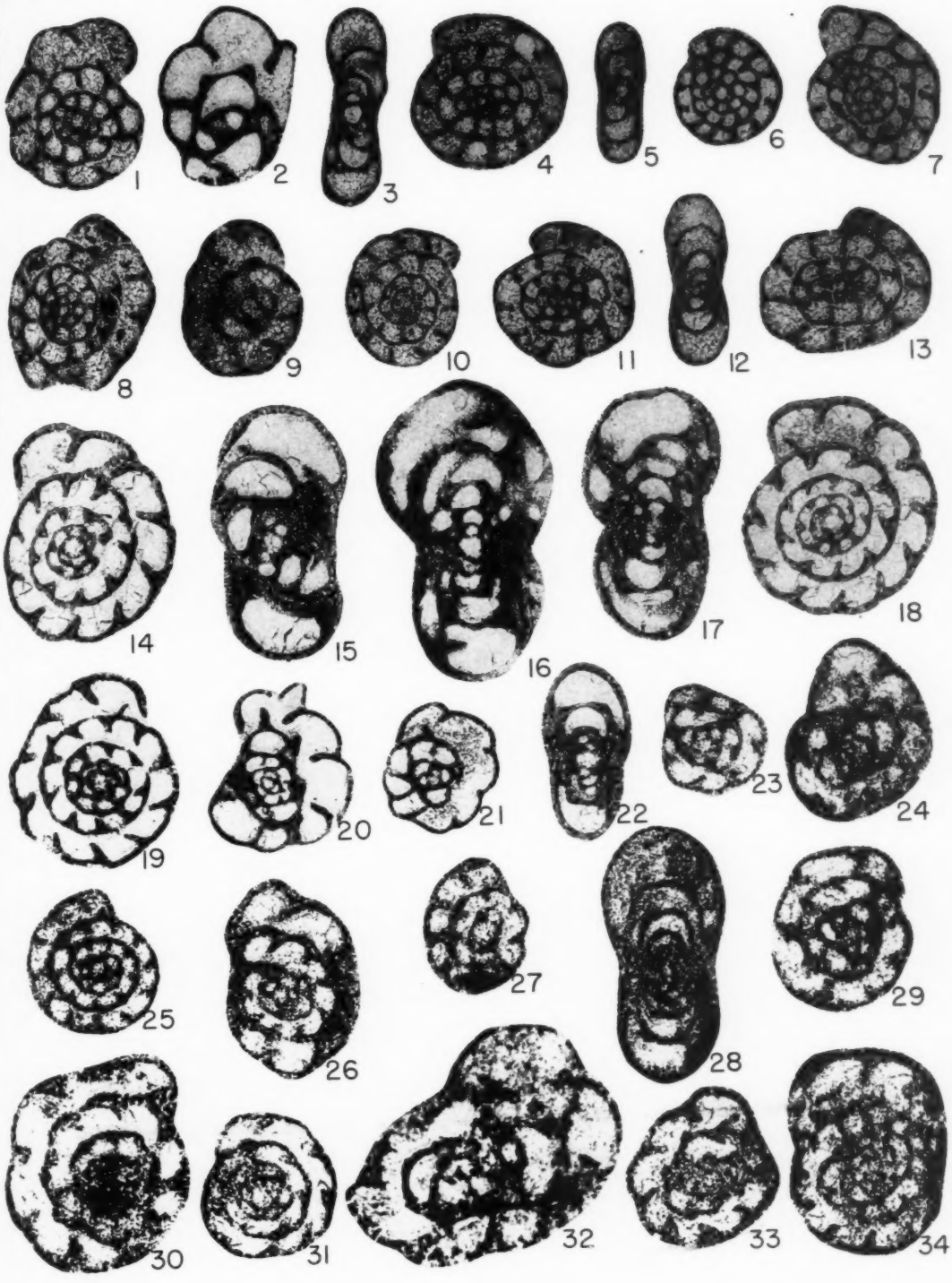
26,27,29—*Plectogyra* sp. Horizontal axial sections; *26*, middle Bed 32; *27,29*, Base Bed 32; Havasu Canyon section.

28—*Endothyra* sp. Axial section, Middle Bed 32, Havasu Canyon section.

30,32—*Plectogyra* sp. Horizontal axial sections, Base Bed 29, Havasu Canyon section.

31,34—*Endothyra* sp. Sagittal sections; *31*, Top Bed 29; *34*, Base Bed 29; Havasu Canyon section.

33—*Plectogyra torquida* E. J. Zeller, n. sp. Horizontal axial section showing secondary deposits, Top Bed 29, Havasu Canyon section.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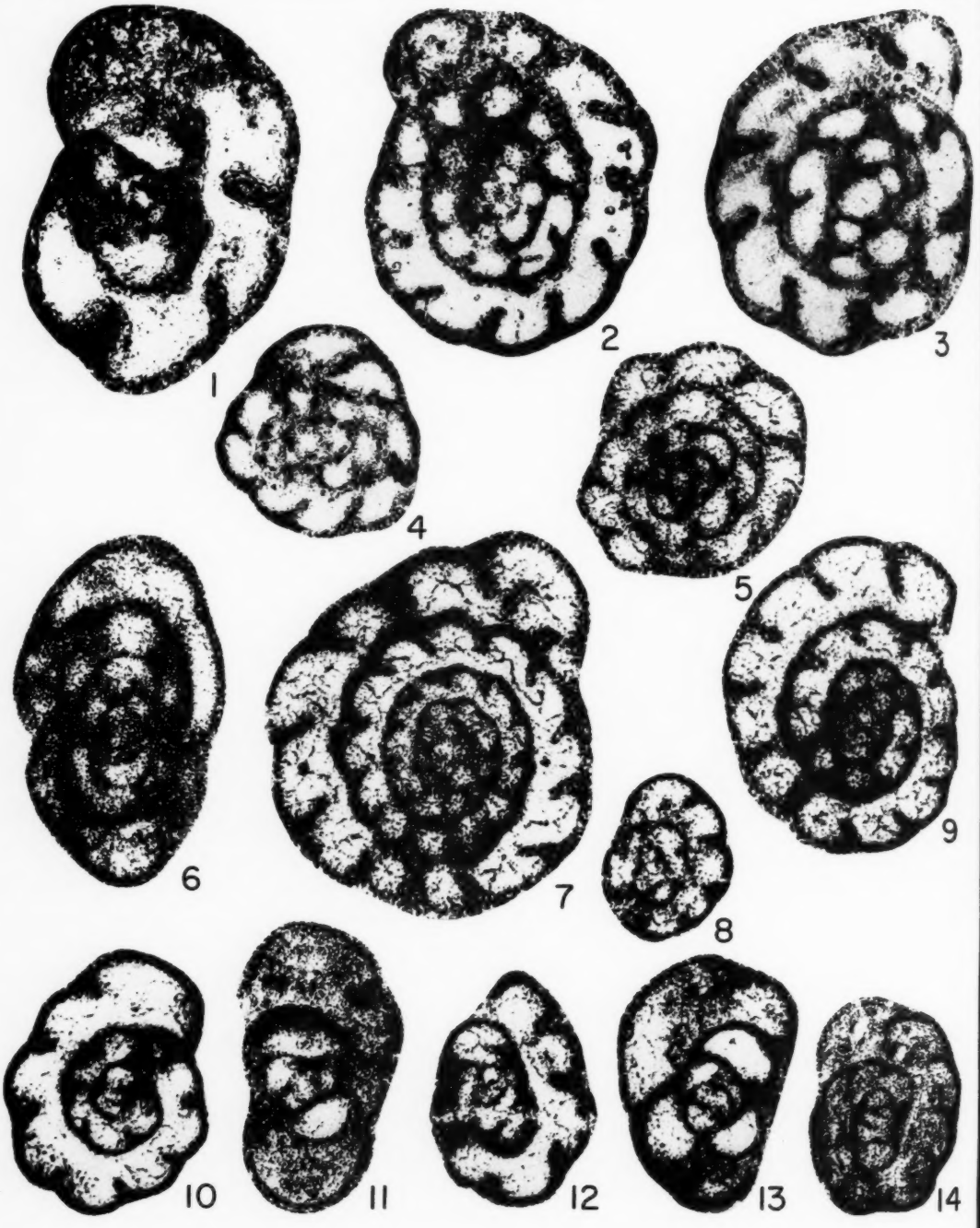
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tionary history of the Foraminifera. Shells of foraminifers are found in many of the Lower Paleozoic rocks but they cannot be said to be really abundant until Mississippian time when the endothyroids themselves became so numerous as to be classed as rock-formers. Probably more significant than the mere appearance of the group in great numbers is the fact that the endothyroids were the first foraminifers to be able to form shells of calcium carbonate.

The question of whether endothyroids actually precipitated their shells directly or whether they agglutinated small particles of calcium carbonate is still undecided. In primitive genera such as *Granuliferella*, the wall appears to be made up of irregular grains and it probably is the result of a process of agglutination of calcareous granules. All specimens show this characteristic to a greater or lesser degree depending upon the preservation. The more advanced endothyroid genera, such as *Endothyra* and *Plectogyra*, are certainly able to precipitate and resorb calcium carbonate chemically as secondary deposits within their shells. Detailed examination of shell microstructure is of only limited value, however, in deciding between precipitation versus agglutination as the prime process for shell formation in these advanced genera. Most of the apparently well-preserved specimens have extremely fine-grained wall structure. The finely granular nature of the wall is visible only under magnifications of over 200 times. Whether these minute granules are original particles of the shell or whether they are the result of recrystallization cannot be decided upon this criterion alone. Most of the specimens examined show a type of fine mosaic structure which strongly suggests recrystallization. Since there is no question that the protoplasm was capable of chemical precipitation of the secondary deposits, it seems likely that the shells were also precipitated by the protoplasm. In any case, even if only the secondary deposits are considered, the ability to handle calcium carbonate in solution rather than as solid grains clearly represents a significant evolutionary achievement.

SECTIONS SAMPLED

Stratigraphic terminology.—It is not the function of this paper to enter into the controversy over terminology of the stratigraphic units in the Mississippian of the Rocky Mountain Region. In describing the sections which have been sampled, an effort has been made to use those stratigraphic names which are currently in use in the area in which the section is located. Whenever possible correlation with widespread lithologic units is indicated. In some of the more remote collecting localities situated some distance from previously described sections, names of correlative formations have been used. In doing this the intention has been to make specific identification of a particular unit clear to other workers even though they may prefer to use another name for the unit.

Chiricahua Mountain Section.—The section found in the Chiricahua Mountains was measured and sampled at the south end of the mountains east of the town of Paradise in Cochise County, Arizona (Text-Fig. 1). Two formations are present, the Escabrosa which consists mainly of crinoidal limestone, approximately 550 feet thick, and the Para-

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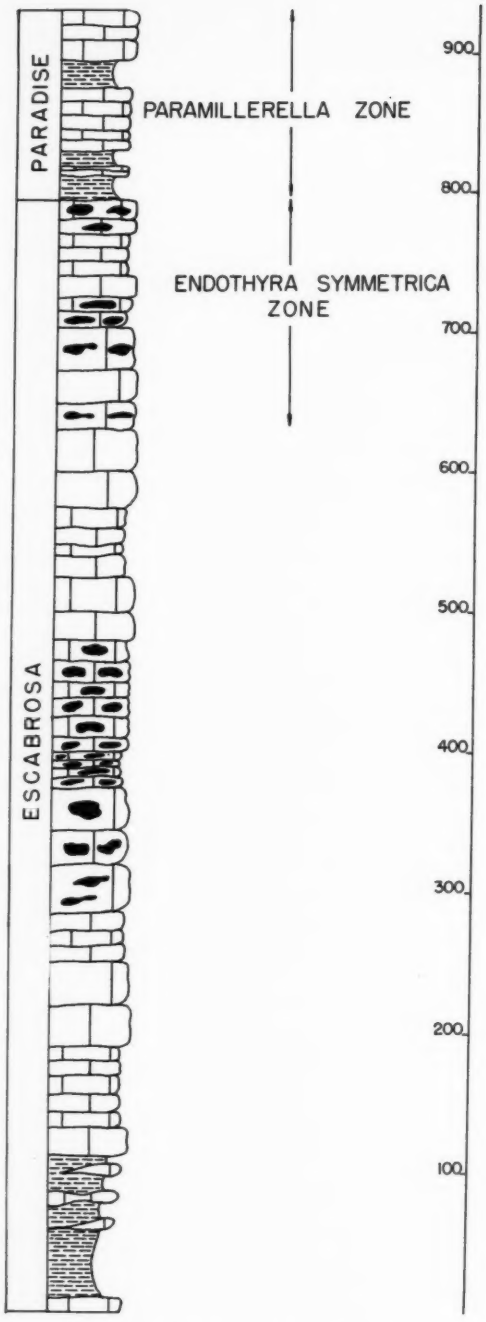
EXPLANATION OF PLATE 76

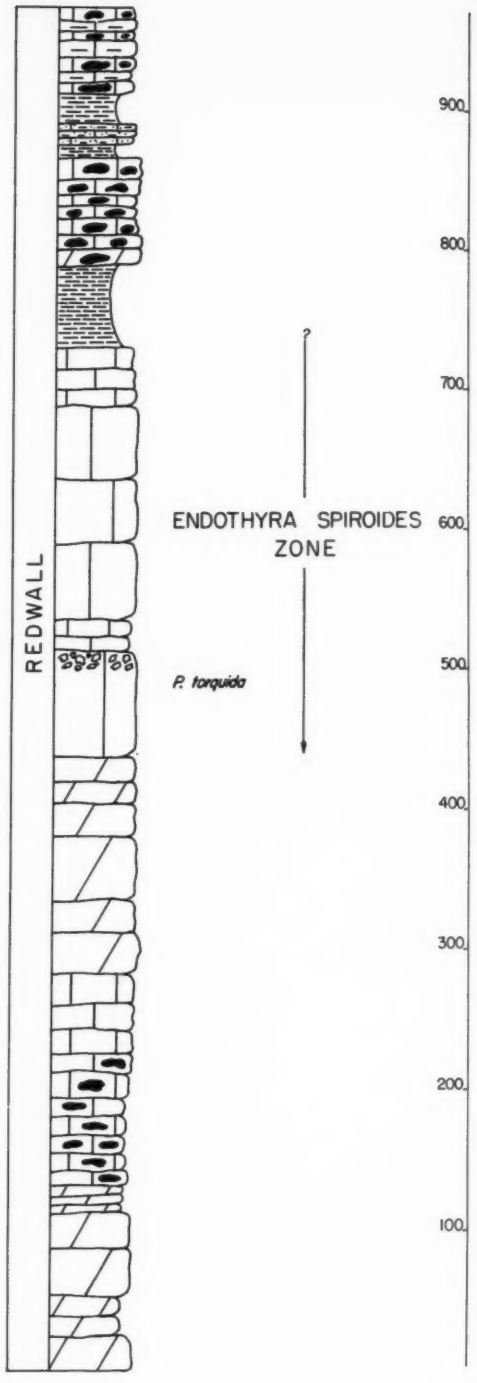
All figures, ×100

FIG. *1,4—Plectogyra* sp. Horizontal axial sections, Middle Bed 25, Frenchman Mountain section.
2—Endothyra sp. Oblique section, Middle Bed 25, Frenchman Mountain section.
3—Plectogyra nevadaensis E. J. Zeller, n. sp. Horizontal axial section of the holotype showing large proloculus, Middle Bed 25, Frenchman Mountain section.
5—Plectogyra sp. Horizontal axial section, Base Bed 23, Frenchman Mountain section.
6—Endothyra spiroides E. J. Zeller, n. sp. Axial section, Base Bed 23, Frenchman Mountain section.
7,9—Endothyra spiroides E. J. Zeller, n. sp. Sagittal sections, Base Bed 23, Frenchman Mountain section.
8,10,12,14—Plectogyra sp. Horizontal axial sections, Bed 56, Nopah Range section.
11,13—Plectogyra sp. Oblique sections, Bed 56, Nopah Range section.



CHIRICAHUA MOUNTAIN SECTION

TEXT-FIG. *1*—Section exposed in Chiricahua Mountains.



HAVASU CANYON SECTION

TEXT-FIG. *2*—Section measured in Havasu Canyon, Utah.

dise which is an alternating sequence of yellowish limestones and fossiliferous grey shales about 130 feet thick. The lowermost beds of the Escabrosa consist of black fissile shales which may be of Devonian age. No fossils other than *Sporangites* were seen in them. The shales rest upon the Martin formation which is of Devonian age. Oolitic beds of the Naco formation of Pennsylvanian age overlie the Paradise.

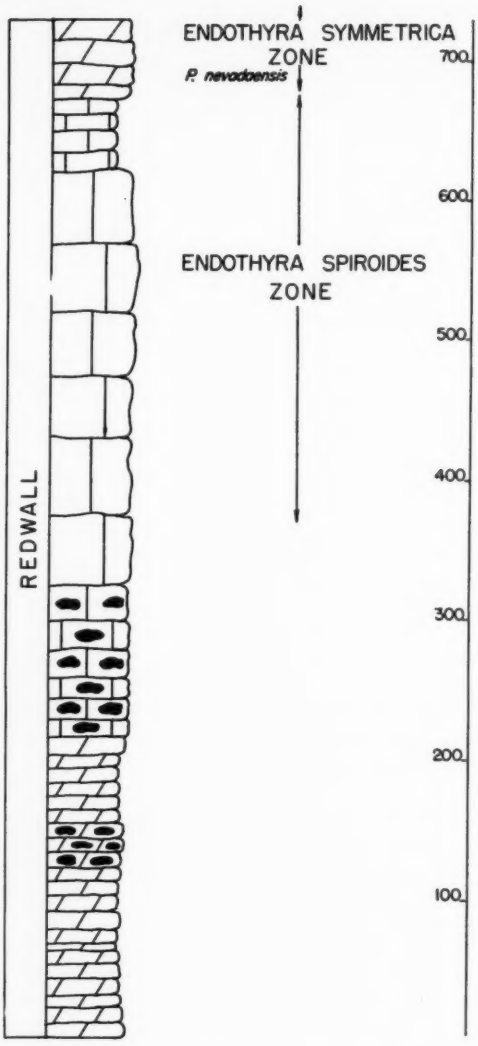
One bed near the top of the Escabrosa has yielded an endothyroid fauna which is definitely of Meramecian age. No endothyroids have been obtained from any of the lower beds in the Escabrosa. However, these lower beds are usually considered to be of Osagian or Kinderhookian age (Stoyanow, 1936). The Paradise formation has yielded an exceptionally abundant fauna which is of special interest because it can be compared directly with that of the Chesteran type section in the Mississippi Valley. Transitional forms between *Paramillerella* and *Endothyra* may be present in this section. The specimens studied suggest that the Paradise would be best correlated with the lower and middle portions of the Chesteran.

Havasu Canyon Section.—This section was measured and sampled in the canyon of Havasu Creek north of the town of Supai in T. 33 N., R. 4 W., Coconino County, Arizona (Text-fig. 2). A single formation, the Redwall limestone, is present. Its total thickness is 969 feet. The Redwall rests upon the Temple Butte formation of Devonian age and is overlain by the Supai sandstone of Pennsylvanian or possibly Permian age. The lower 456 feet of the Redwall here consists of dolomite and contains no endothyroids. The dolomite terminates abruptly at the top and is overlain by a light-colored crystalline limestone unit about 80 feet thick. This unit is of especial importance because it contains endothyroid foraminifers of Meramecian age. A marked brecciated zone with thin shale partings is developed at the top of the 80-foot limestone, and this may represent an unconformity. Limestones which overlie the brecciated zone also contain Meramecian endothyroids, although the foraminifers are limited to comparatively few beds. The upper portion of the limestone sequence becomes shaly and sandy at the top, so that the contact with the overlying Supai is not as sharp as might be expected. No endothyroids were obtained from the beds directly underlying the Supai so that the age of the upper portion of the Redwall could not be ascertained.

South Muddy Mountains Section.—This section was measured at the south end of the Muddy Mountains on the west slope and along the crest of the southernmost peak known as Frenchman Mountain (Text-fig. 3). Frenchman Mountain is located in T. 20 S., R. 36 E., Clark County, Nevada. The lower portion of the Redwall is dolomitic in this section as it was in the Havasu Canyon section, but the dolomitic phase is only 218 feet thick. The first endothyroid zone occurs about 150 feet above the top of the dolomite. Here, also, the endothyroids are Meramecian in age and seem to correlate with the *Endothyra spiroides* zone occurring in the lower portion of the Brazer limestone in the sections studied in Utah.

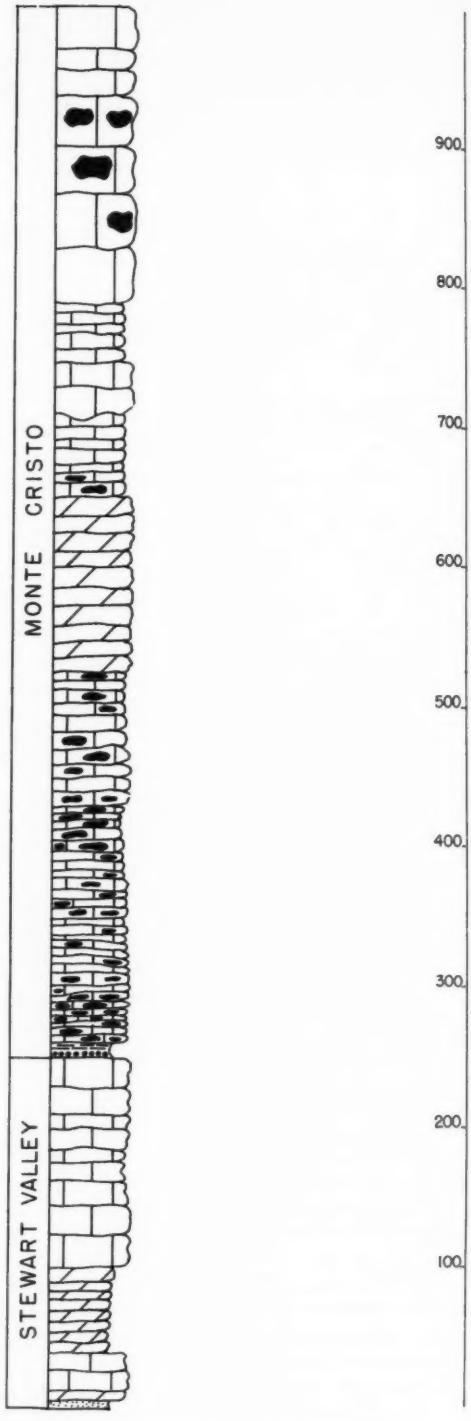
A second zone is found about 300 feet above the lower endothyroid zone which contains Meramecian forms. No important physical break is visible between these zones. The total thickness of the Redwall is 733 feet in the South Muddy Mountains section.

Nopah Range Section.—The Nopah Range section was measured at the north end of the Nopah Range, Inyo County, California (Text-fig. 4). The total thickness of the Mississippian seems to be about 1,237 feet. Hazzard (1937), who originally described the section, divided the Mississippian rocks into two units, the Stewart Valley formation below and the Monte Cristo formation above. The Stewart Valley rests upon the Sultan dolomite of Devonian age, but the contact which Hazzard has picked as the boundary between the Devonian and Mississippian may be too low. He includes 400 feet of massive pinkish and greyish oolitic dolomite at the base of the Stewart Valley in the Mississippian. Only a few orthoconic cephalopods were found in these beds, and their exact age is uncertain. The dolomitic beds were sectioned extensively but no endothyroids were found in them. The dolomitic sequence is terminated at the top by a distinct and possibly angular unconformity. Thin sandstone and conglomerate beds are developed along this unconformity. The re-



SOUTH MUDDY MOUNTAIN SECTION

TEXT-FIG. 3—Section exposed in South Muddy Mountains, Nevada.



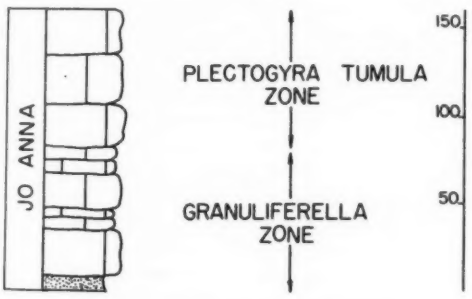
NOPAH SECTION

TEXT-FIG. 4—Section in the Nopah Range, California.

maining 250 feet of beds are markedly different from those below the unconformity. They contain abundant fossils, mostly corals and small brachiopods, and the uppermost member of the Stewart Valley contains the only endothyroid fauna in the entire section.

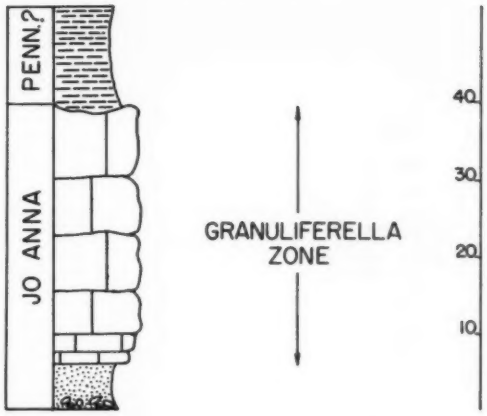
Overlying the Stewart Valley is the Monte Cristo limestone which is very cherty and siliceous in its lower 300 feet and gradually becomes more coarsely crinoidal toward its top. The Monte Cristo, though thin-sectioned extensively, yielded no endothyroids, and its age is uncertain. The total thickness of the Monte Cristo as exposed in this section is 987 feet. However, the upper beds may be cut out as a result of faulting and the true thickness of the section may not be shown.

South Confusion Range Section.—The South Confusion Range section is located two miles east of Conger Spring near the south end of the Confusion Range in Millard County, Utah (Text-fig. 5). The total thickness of the lower Mississippian limestone in this section is about 160 feet. This formation, usually called the Jo Anna, is a Madison equivalent. Shales and limestones containing Mississippian fossils are known to overlie this lower limestone bed in other sections in the vicinity. In the South Confusion Range, the *Granuliferella* zone and the *Plectogyra tumula* zone are present in the Jo Anna. Both of these zones are found at many places in the Madison limestone of the north Cordilleran Region. The Jo Anna



SOUTH CONFUSION RANGE SECTION

TEXT-FIG. 5—Section measured in South Confusion Range, Utah.

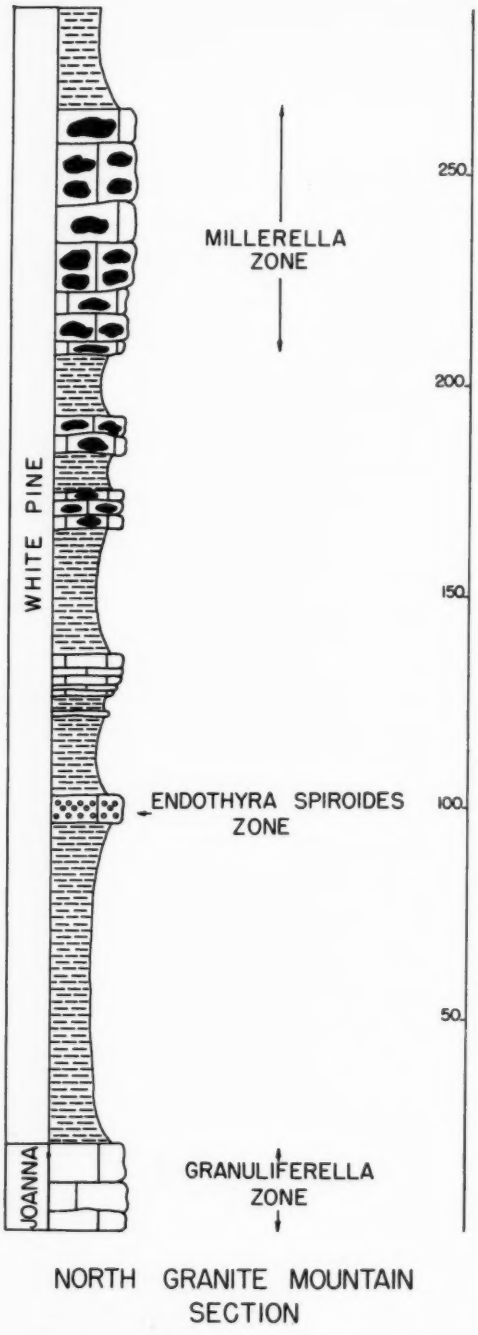


BISHOP SPRINGS SECTION

TEXT-FIG. 6—Section measured at Bishop Springs, Utah.

limestone rests disconformably upon shales containing a brachiopod fauna of Devonian age. Endothyroids are abundant and are distributed throughout the thickness of the limestone. Dark silty shales which contain a few thin limestone lenses overlie the Jo Anna in this area. *Paramillerella* has been obtained from some of these lenses but the exact age of the forms is uncertain. It should be noted that the Confusion Range is an area of exceedingly complex stratigraphic and structural relationships and that extreme local variations in sections are to be found. (Youngquist, 1949; Ogden, 1950).

Bishop Springs Section.—The Bishop Springs section is located on the northwestern flank of the Confusion Range at the crest of the Bishop Springs anticline in Millard County, Utah (Text-fig. 6). Here the total thickness of Mississippian rocks is 40 feet. As in the South Confusion section, the Mississippian limestone rests disconformably upon Devonian shales. Only the *Granuliferella* zone found in the South Confusion section was found in the Bishop Springs section, indicating that most of the thinning is due to removal by erosion or non-deposition of the upper portions of the limestone. The Mississippian is directly overlain by Pennsylvanian rocks in this area, the Zone of *Profusulinella* occurring only 250 feet above the top of the Mississippian. The Zone of



TEXT-FIG. 7—Section measured at North Granite Mountain, Utah.

Profusulinella occurs about 1,180 feet above the top of the Mississippian in the South Confusion Range. There is much direct evidence to indicate that deformation occurred north of this area throughout all of Mississippian time, and it is certain that this deformation influenced Mississippian sedimentation. Although later thrusting in the area has complicated the picture greatly, the Bishop Springs anticline must have existed as a low anticlinal structure during Meramecian time and apparently persisted as a positive area into the lower Pennsylvanian.

North Granite Mountain Section.—The North Granite Mountain section is exposed in the low hills northeast of Granite Mountain at the extreme north end of the Confusion Range (Text-fig. 7). It is about five miles west of Coyote Spring which is located in White Valley south of the Fish Springs Range. The section here includes three distinct limestone units. The lowermost unit carries the *Granuliferella* fauna which is the same as that found in the lower beds of the South Confusion section and in the Bishop Springs section. This lowermost limestone unit which is light-colored and coarsely crystalline is overlain by a dark somewhat silty shale. The shale weathers to a yellowish or purplish color and contains a few beds of pelecypods. The next unit is always thin, never attaining a thickness of more than 10 feet, and normally being less than 5 feet in thickness. It is a nearly black oolitic limestone which is readily distinguished in the field by its large horn coral fauna. It carries an especially abundant endothyroid fauna which includes *Endothyra spiroides*, and this zone probably correlates with the cephalopod zone (Youngquist, 1948) at Skunk Springs south of Cowboy Pass.

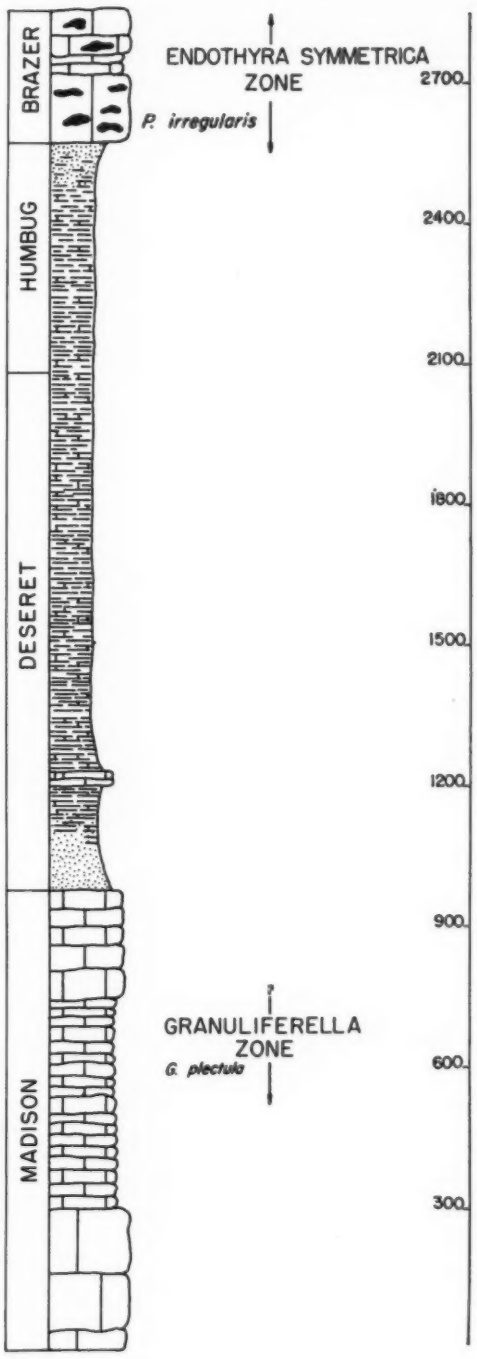
This black oolitic limestone is overlain by a shale which contains thin limestones and which is similar in lithology to the shale occurring below it. No fossils were found in the upper shale. The upper shale is overlain by a dense, dark grey limestone carrying abundant nodules and bands of black chert. Endothyroids are uncommon in this unit, but those examined seem to be of Chesteran age.

At this particular locality the top of the section is cut off by a thrust which brings Devonian limestone into contact with the

Chesteran. Good evidence for Mississippian tectonic activity can be found at another locality about 3 miles northwest of the section where the black oolite rests directly upon the lowermost limestone unit, with the entire intervening shale missing. Five miles southeast of the measured section the black chert-bearing limestone rests directly upon shales of Devonian age. Much of the evidence gathered indicates that the folding which took place in this area culminated in Meramecian time.

South Cedar Mountain Section.—The South Cedar Mountain section is an incomplete Mississippian section measured in T. 5 S., R. 9 W., at the south end of the Cedar Mountains facing Skull Valley, Toelle County, Utah. The total section measured is 349 feet thick, all of which is Meramecian in age. No rocks equivalent in age to the Madison are thought to be exposed anywhere in the South Cedar area. The section is located in a highly faulted and intruded area, and the exact nature of the rocks which overlie and underlie it cannot be determined with certainty. It appears that the section is both underlain and overlain by conglomeratic beds. The Mississippian is known to be overlain by beds of lower Pennsylvanian age, but the contact is not visible. The section is known to be underlain by a thick sandstone and some conglomeratic beds which are in turn considered to be underlain by a lower limestone sequence of uncertain age, possibly Meramecian.

Lakeside Section.—The Lakeside section is located in the Lakeside Mountains south of the town of Lakeside in T. 4 N., R. 9 W., Box Elder County, Utah (Text-fig. 8). Four formations are present in the Mississippian rocks of this section. The Madison is at the base and has a total thickness of 1,025 feet. It rests upon the Jefferson formation of Devonian age. The Madison consists of coarsely fragmental and crinoidal limestones with a few beds of cross-bedded oolite. Only the *Granuliferella* zone can be identified positively in the Madison in this section. The highest beds do not contain endothyroids, but they may be equivalent in age to the *Plectogyra tumula* zone.



LAKESIDE SECTION

TEXT-FIG. 8—Section measured at Lakeside Mountain, Utah.

The Deseret formation is 1,052 feet thick. It contains a lower zone of shale and thin sandstone and a much thicker upper zone of thin-bedded silty to sandy limestone. No endothyroids are present in the Deseret formation.

The Humbug overlies the Deseret and has a total thickness of 520 feet. Its lithology is similar to that of the Deseret, except that the beds are somewhat more platy and resistant. In general, the Humbug is less sandy and shaly than the Deseret.

The youngest formation in the Lakeside section is the Brazer limestone which contains an abundant endothyroid fauna of Meramecian age. The Brazer has a total thickness of 278 feet in this section, and it is possible that some of the upper portion of the formation has been cut out by faulting. Other exposures of the Brazer which outcrop northwest of the town of Lakeside show approximately the same thickness for the Brazer limestone, and these exposures show the lower Pennsylvanian beds in contact with the Brazer.

Blacksmith Fork Canyon Section.—The Blacksmith Fork section is located in the Bear River Range which is an extension of the northern Wasatch Mountains (Text-fig. 9). The section was sampled in Leatham Hollow, a steep side canyon off the left fork of Blacksmith Fork Canyon in Cache County, Utah. Both Madison and Brazer are present in this section. The Madison is approximately 765 feet thick, the lower 60 feet consisting of thin-bedded dense limestone and occasional thin shales. The Madison rests upon beds of Devonian age, and there is some question as to the exact age of the black shales at its base. No endothyroids are present in the lowermost 200 feet of the Madison, but both the *Granuliferella* and *Plectogyra tumula* zones are found in the upper part of the formation.

The Brazer has an aggregate thickness of about 2,300 feet. It consists of three principal units. The lower unit is a massive quartzite which grades upward into a silty, dense, thin-bedded shale. This unit probably corresponds to the Deseret of the Lakeside section. A shaly or silty, thin-bedded limestone overlies the lower unit. This limestone is probably correlative with the Humbug of the Lakeside section. The uppermost unit of the Brazer is approximately 1,650 feet thick. It consists predominantly of limestone with some dolomitic beds near its base. Most of this unit carries an abundant endothyroid fauna. It is considered possible to distinguish two endothyroid zones within the Meramecian part of this section. The lower zone carries the *Endothyra spiroides* fauna which is remarkably similar to that of the Salem limestone of Indiana. The fauna of the upper endothyroid zone includes *Endothyra symmetrica* and is similar to that pres-

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EXPLANATION OF PLATE 77

All figures, ×100.

FIG. *1*—*Granuliferella granulosa* E. J. Zeller, n. sp. Horizontal axial section, Bed 1, Bishop Springs section.

2—*Granuliferella* sp. Oblique section, Bed 1, Bishop Springs section.

3—*Granuliferella tumida* E. J. Zeller, n. sp. Oblique section, Bed 3, Bishop Springs section.

4—*Granuliferella* sp. Horizontal axial section, Bed 3, Bishop Springs section.

5,6—*Plectogyra tumula* E. J. Zeller, n. sp. Horizontal axial sections; *5*, Bed 17; *6*, Bed 20; South Confusion Range section.

7,8,14,19,20—*Granuliferella granulosa* E. J. Zeller, n. sp. Horizontal axial sections; *7,8*, Bed 20; *14*, Bed 6; *19,20*, Bed 2; South Confusion Range section.

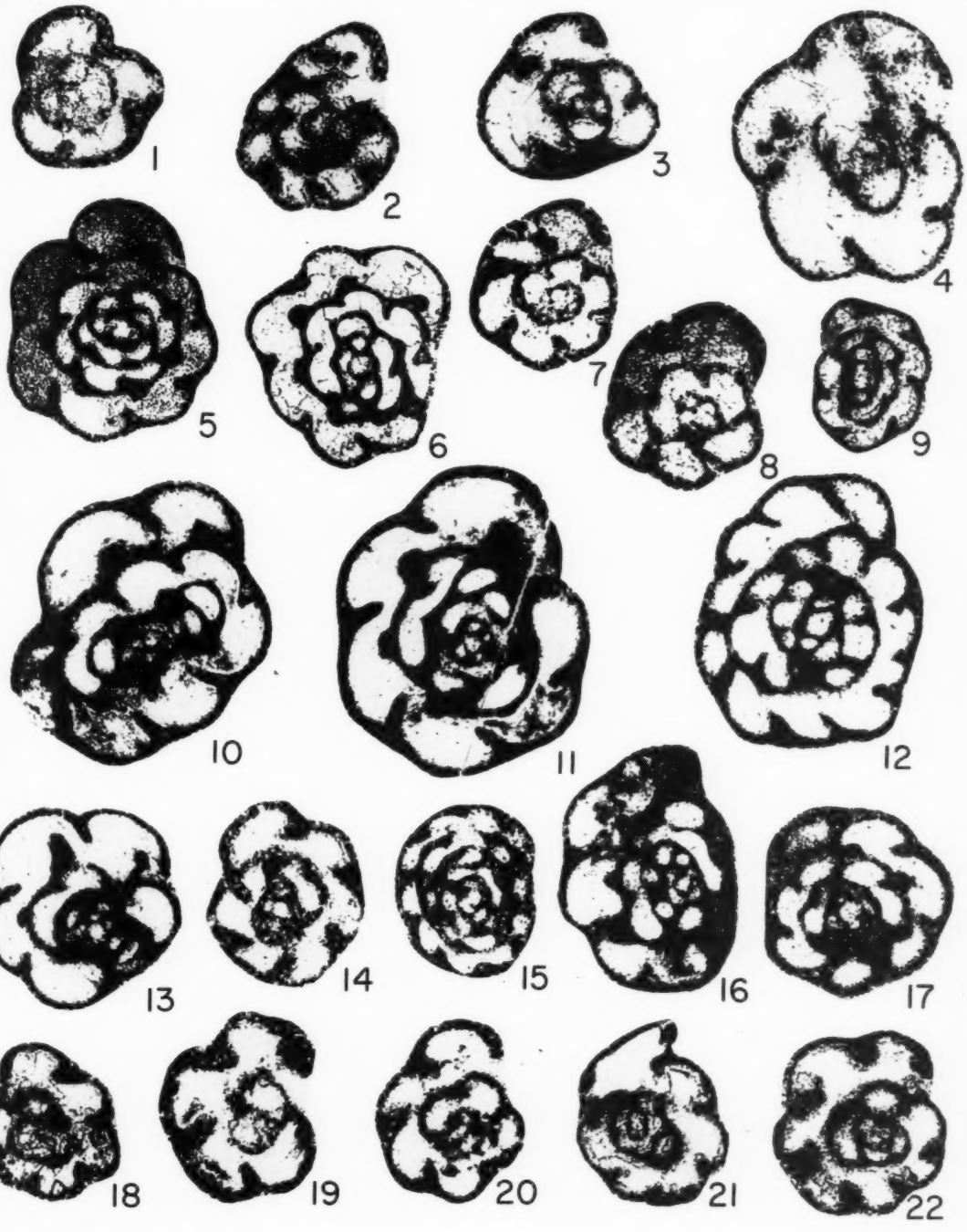
9—*Plectogyra* sp. Horizontal axial section, Bed 20, South Confusion Range section.

10,12,13,15,16,17—*Plectogyra* sp. Oblique sections of various forms; *10,12,13,15,16*, Bed 14; *17*, Bed 17; South Confusion Range section.

11—*Plectogyra tumula* E. J. Zeller, n. sp. Horizontal axial section of form showing greater than normal total angular distortion, Bed 14, South Confusion Range section.

18—*Granuliferella plectula* E. J. Zeller, n. sp. Horizontal axial section, Bed 1, South Confusion Range section.

21,22—*Granuliferella tumida* E. J. Zeller, n. sp. Horizontal axial sections, Bed 6, South Confusion Range section.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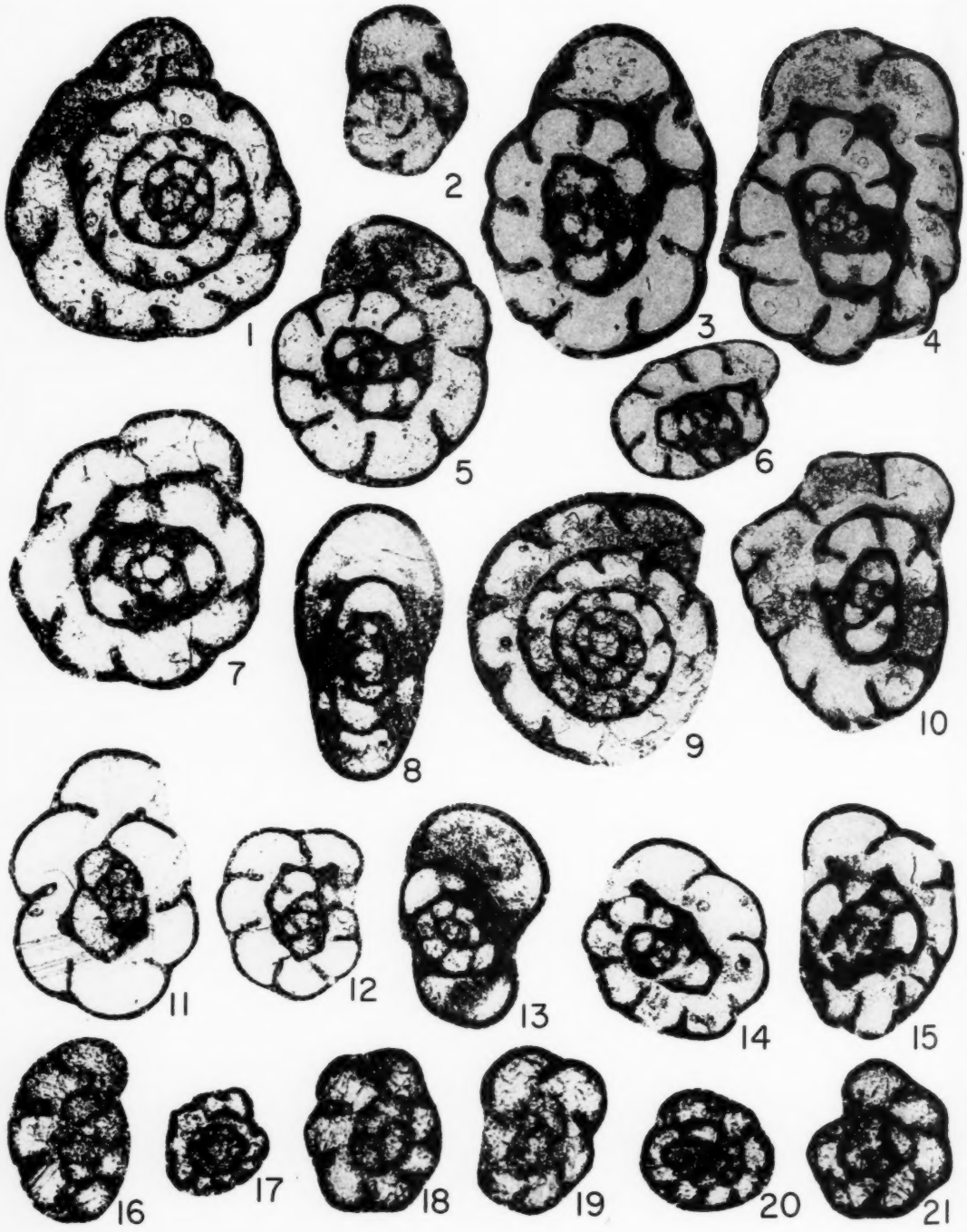
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ent in the Ste. Genevieve of the Mississippi Valley. Additional forms are present, however, which do not occur in the rocks of the Mississippi Valley area. The Brazer is overlain by shales and limestones of the basal Wells formation of Pennsylvanian age.

South Teton Section.—The South Teton section was measured and sampled in a gully on the east face of Glory Mountain at the south end of the Teton Range, T. 41 N., R. 119 W., Teton County, Wyoming (Text-fig. 10). The Madison is the only Mississippian formation present, and it has a total thickness of 737 feet. It rests upon the Darby formation of Devonian age and is overlain by the Amsden formation of uncertain age.

The entire Madison section consists of limestones which contain abundant endothyroids. Lodgepole and Mission Canyon members are considered to be distinguishable, the Lodgepole making up the lower 385 feet and the Mission Canyon comprising the upper 352 feet. In this section the boundary between the *Granuliferella* zone and the *Plectogyra tumula* zone does not seem to coincide with the boundary between the Lodgepole and Mission Canyon. In general, Lodgepole and Mission Canyon are distinguished by their lithologic differences and in many sections the contact is gradational (Pitrat, 1956). Since this lithologic change probably represents a change in conditions of sedimentation rather than an hiatus, an abrupt change in faunas would not be expected.

Fairy Lake Section.—The Fairy Lake section was measured and sampled in the cirque above Fairy Lake in the Bridger Mountains, T. 2 N., R. 6 E., Gallatin County, Montana (Text-fig. 11). The section consists of about 610 feet of Lodgepole and approximately 380 feet of Mission Canyon. The latter thickness represents only the lower half of the Mission Canyon. The base of the section rests upon the Three Forks formation of Devonian age. The lowest endothyroid-bearing rocks in the section occur 498 feet from the base and near the top of the Lodgepole member. This fauna includes species which are assigned to the upper Madison *Plectogyra tumula* zone. Rocks from the lower portion of the Lodgepole were extensively thin-sectioned, but no endothyroids were found. The lithology of the lower portion of the Lodgepole is of a nature that has rarely been found to contain foraminifers in any of the sections studied. Al

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EXPLANATION OF PLATE 78

All figures, ×100

FIG. *1*—*Endothyra* sp. Sagittal section, Bed 3, South Cedar Mountains section.

2—*Granuliferella granulosa* E. J. Zeller, n. sp. Horizontal axial section, Bed 3, South Cedar Mountains section.

3,4—*Plectogyra rugosa* E. J. Zeller, n. sp. Horizontal axial sections; *3*, Bed 1; *4* is the holotype showing the secondary deposits, Bed 4; South Cedar Mountains section.

5—*Plectogyra* sp. Horizontal axial section, Bed 3, South Cedar Mountains section.

6—*Plectogyra irregularis* E. J. Zeller, n. sp. Horizontal axial section, Bed 4, South Cedar Mountains section.

7—*Plectogyra torquida* E. J. Zeller, n. sp. Horizontal axial section of the holotype, Base Bed 23, Lakeside Mountains section.

8—*Endothyra symmetrica* E. J. Zeller, n. sp. Axial section, Bed 8, South Cedar Mountains section.

9—*Endothyra symmetrica* E. J. Zeller, n. sp. Sagittal section, Base Bed 23, Lakeside Mountains section.

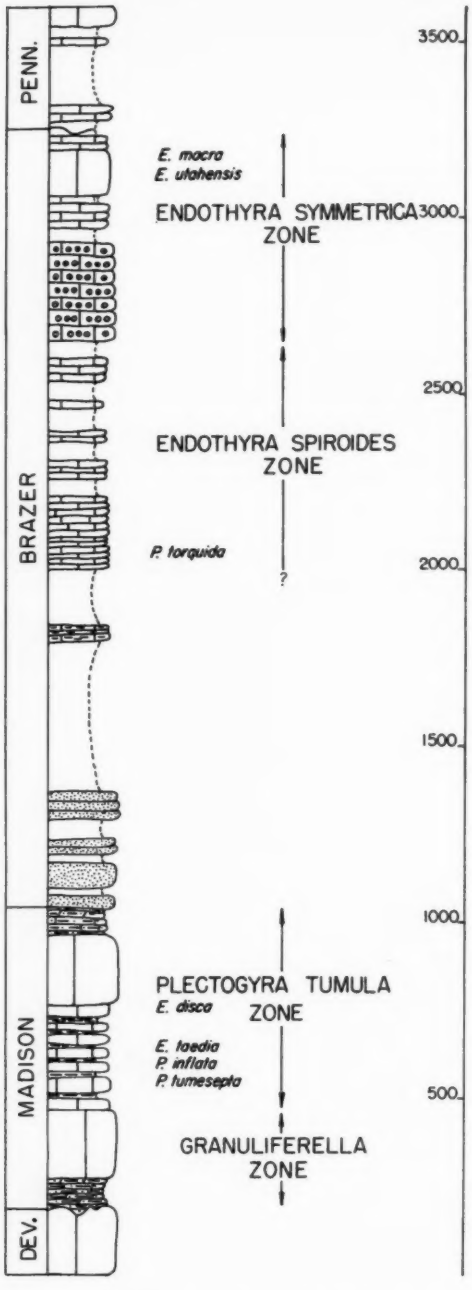
10,11—*Plectogyra* sp. Horizontal axial sections, Base Bed 23, Lakeside Mountains section.

12,14,15—*Plectogyra irregularis* E. J. Zeller, n. sp. Horizontal axial sections, Base Bed 23, Lakeside Mountains, section; *14* is the holotype.

13—*Plectogyra irregularis* E. J. Zeller, n. sp. Vertical axial section, Top Bed 23, Lakeside Mountains section.

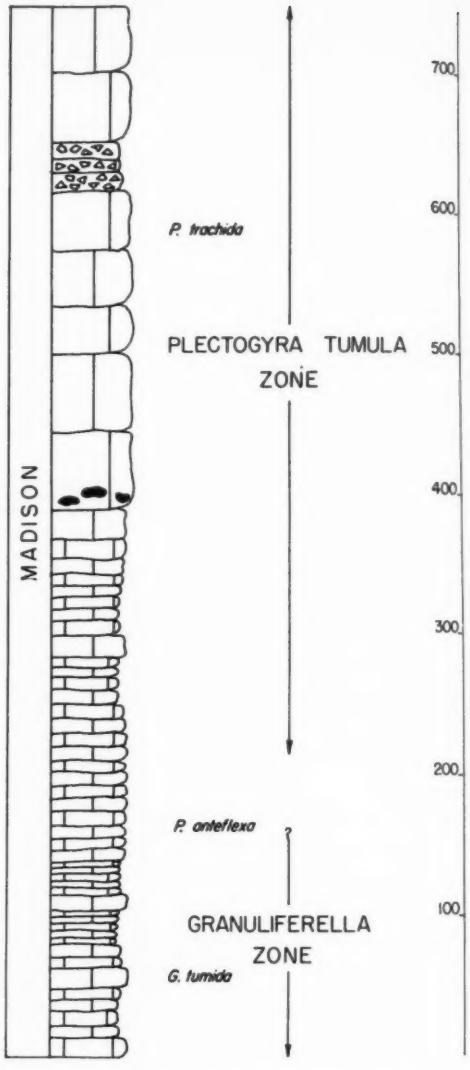
16,17,20—*Granuliferella* sp. Horizontal axial sections, Middle Bed 17, Lakeside Mountains section.

18,19,21—*Granuliferella plectula* E. J. Zeller, n. sp. Horizontal axial sections, Middle Bed 17, Lakeside Mountains section; *21* is the holotype.



BLACKSMITH FORK SECTION

TEXT-FIG. *9*—Section measured at Blacksmith Fork Canyon, Utah.



SOUTH TETON SECTION

TEXT-FIG. *10*—Section measured at South Teton, Wyoming.

of the samples collected from the Mission Canyon formation contain a fauna identical to that found in the upper Madison limestone of other areas. It is significant to note that in the Fairy Lake section, also, the boundary between the Lodgepole and Mission Canyon does not mark the boundary between the upper and lower endothyroid zones.

DEFINITION OF NEW TERMS

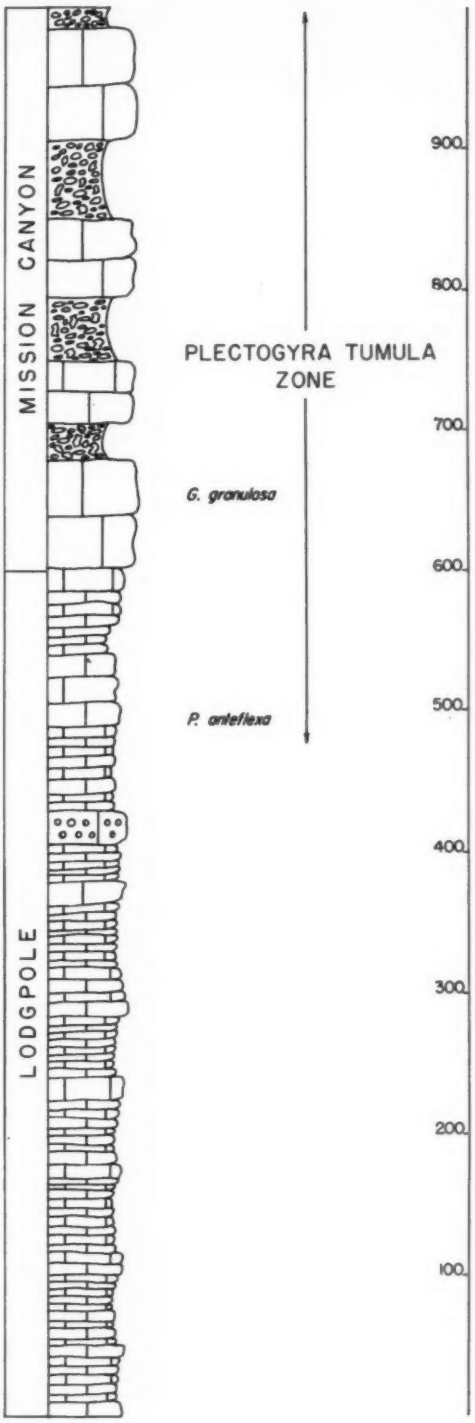
The secondary deposits which occur within the shells of several of the genera of endothyroid foraminifers have no convenient terms for their designation. Three new terms are proposed here which may be helpful in defining the general shape of the deposits which frequently occur on the floor of the chambers. The term *tumulus* (Latin: "a little hill") shall be used to indicate that type of secondary deposit which appears in cross-section as a more or less symmetrical node with a rounded summit. The term *acanthus* (Latin: "a thorn") shall be used to indicate a secondary deposit which is sharply pointed but not curved toward the anterior. The term *hamulus* (Latin: "a hook") shall be used to designate a hook-shaped secondary deposit in which the point of the hook is directed toward the anterior.

STRATIGRAPHIC ZONATION

The endothyroid foraminifers are considered to be of special value in the stratigraphic zonation of the thick Mississippian limestones of the Cordilleran Region. Their abundance and wide distribution throughout the area and their short vertical ranges make them useful as zone markers. Many species have wide geographic distribution while maintaining comparatively restricted stratigraphic ranges. In general, the faunal zones proposed here are based upon the entire ranges of zone markers since the older species frequently carry over into the higher zones.

LOWER MISSISSIPPIAN ZONES

Granuliferella Zone.—The *Granuliferella* zone includes the middle and the lower portions of the Lodgepole and its equivalents in the Madison formation. This zone is characterized by the abundance of this genus to the exclusion of other genera of endothyroid foraminifers. It is considered to be Kinderhookian in age. The *Granuliferella* zone is present in the South Confusion Range section, Utah, the Bishop Springs section, Utah, the North Granite Mountain section, Utah, the Lakeside section, Utah, the Blacksmith Fork Canyon section, Utah, and the South Teton section, Wyoming. The lower



TEXT-FIG. *11*—Section measured at Fairy Lake, Montana.

unfossiliferous portion of the Fairy Lake section, Montana, is also considered to be included in the *Granuliferella* zone.

Plectogyra tumula Zone.—The rocks of the Mission Canyon and the upper Lodgepole and their equivalents in the Madison formation contain abundant specimens of the distinctive and easily recognized species, *Plectogyra tumula*, and this part of the section is referred to as the *Plectogyra tumula* zone. The *Plectogyra tumula* zone is probably Osagian in age for the most part; however, direct correlation with Mississippi Valley forms has not yet been possible. Beds belonging in this zone are present in the South Confusion section, Utah, the Blacksmith Fork section, Utah, the South Teton section, Wyoming, and the Fairy Lake section, Montana. Besides the presence of *Plectogyra tumula*, the zone contains a large number of other characteristic species of both *Plectogyra* and *Endothyra*. In particular, *Plectogyra anteflexa* shows nearly as wide distribution as *Plectogyra tumula*, though it is restricted to the lower portion of the zone. Further work may permit splitting the *Plectogyra tumula* zone into two smaller units through the use of *Plectogyra anteflexa* in the lower portion and some other species for the upper unit.

UPPER MISSISSIPPIAN ZONES

Endothyra spiroides Zone.—The *Endothyra spiroides* zone includes roughly the lower half of the Meramecian rocks of the Cordilleran Region. These rocks are not widespread in the area, but they contain a fauna which is similar in many respects to that of the Salem limestone of Indiana. The *Endothyra spiroides* zone is represented in the lower portion of the Meramecian rocks of the Havasu Canyon section, Arizona, the South Muddy Mountains section, Nevada, and the Blacksmith Fork Canyon section, Utah. Other species of *Endothyra* and *Plectogyra* are present, but they are considerably less diagnostic.

Endothyra symmetrica Zone.—The rocks of the Upper Meramecian in the Cordilleran Region are characterized by *Endothyra symmetrica*. The exact correlation of these beds with those of the type section in the Mississippi Valley is not certain, but they probably compare most favorably in age with the upper St. Louis and Ste. Genevieve formations. They may also include Chesteran age equivalents in some stratigraphic sections. Rocks of the *Endothyra symmetrica* zone were probably once much more widespread than they are now. It is considered likely that most of these rocks were removed by erosion prior to the deposition of the Pennsylvanian. Many other forms of *Endothyra* and forms of *Plectogyra* and *Granuliferella* are present in this zone. The Chiricahua Mountain section, Arizona, and the South Cedar Mountain section, Utah, and the Blacksmith Fork section, Utah, include rocks which contain *Endothyra symmetrica*.

Paramillerella Zone.—Only the Paradise formation at the top of the Chiricahua Mountains section, Arizona, shows the typical Chesteran facies of the midcontinent. The primitive fusulinid genus *Paramillerella* is present in abundance throughout the Paradise Formation and the species is identical to the species present in the Glen Dean in the midcontinent (D. Zeller, 1953). One specimen of *Paramillerella* together with several specimens of *Plectogyra* were found in the uppermost beds of the North Granite Mountain section, Utah.

Since the primitive fusulinid genus *Paramillerella* crosses the boundary between the uppermost Mississippian and the lower Pennsylvanian, it may be considered somewhat undesirable to use this genus to identify a stratigraphic zone which can be either Mississippian or Pennsylvanian in age. *Paramillerella* has been selected here for use as a zone marker because it is the most distinctive fossil which is present in the Chesteran rocks of the area. Some of the species of *Plectogyra* which occur in Chesteran rocks may serve as good zone markers, also, but these forms are not present in sufficient abundance for them to be useful in this area without further study.

SYSTEMATIC PALEONTOLOGY

Genus GRANULIFERELLA E. J. Zeller, n. gen.

Type species.—*Granuliferella granulosa* E. J. Zeller, n. sp.

The shell is discoidal, involute, and more strongly umbilicate on one side than on the other. The chambers are large in proportion to the size of the shell. The wall consists of a

single layer and is usually thick in proportion to the size of the shell. The wall is always conspicuously granular though it varies in coarseness among the species. The coiling is plectogyroid and usually shows large total angular distortion. The aperture is narrow and low and is situated at the base of the apertural face. Mature shells rarely show more than two volutions. *Granuliferella* occurs throughout the Madison limestone and its stratigraphic equivalents in Montana, Wyoming, and Utah.

Granuliferella most closely resembles *Plectogyra* but differs from it in the single layered, coarsely granular wall, the smaller number of volutions in the adult shell, and the larger proportional chamber size.

GRANULIFERELLA GRANULOSA
E. J. Zeller, n. sp.
Pl. 77, fig. 1,7,8,14,19,20;
Pl. 78, fig. 2;
Pl. 79, fig. 3,4,5,20,21,22;
Pl. 81, fig. 4,5,7,8,10;
Pl. 82, fig. 6,7

The shell is discoidal, involute, and more strongly umbilicate on one side than on the other. The chambers are large in proportion to the size of the shell, and they are somewhat swollen between the sutures. The septa are short and anteriorly directed. The aperture is low and narrow and is located at the base of the apertural face. The walls of the chambers in the last volution are thick in proportion to the size of the shell, and they show a marked thickening from the relatively thinner wall of the juvenile portion of the shell. The wall consists of a single layer of granular material, probably entirely calcite. Secondary deposits are absent. The coiling is plectogyroid and shows a large total angular distortion. The proloculus is small and frequently indistinct. Adult shells consists of two volutions or less. The diameter of adult shells averages from 0.3 to 0.4 mm.

Remarks.—Granuliferella granulosa differs from *G. plectula* in its thicker wall and larger chambers, as well as its greater angular distortion in coiling.

Occurrence.—Granuliferella granulosa is a long-ranging species occurring throughout the Lower Mississippian limestones of the Cordilleran Region. *G. granulosa*, sometimes associated with other species of *Granuliferella*, makes up the entire endothyroid foraminiferal fauna of the lowermost endothyroid faunal zone in the Mississippian limestones. It occurs in rocks of both Kinderhookian and Osagian age, but by Osagian time other endothyroid genera had appeared. Specimens of *G. granulosa* have been obtained from the basal portion of the Jo Anna limestone in the Bishop Springs and North Granite Mountain sections and from the lower and middle portions of the Jo Anna in the South Confusion Range section. A single specimen was obtained from the lower part of the South Cedar Mountains section where it appears to be associated with Meramecian species of other endothyroid genera. Abundant specimens were found in the middle and upper beds of the Madison in the Blacksmith Fork Canyon section and in the upper beds of the South Teton section. The holotype comes from Bed 7 which is 654 feet above the base of the Madison in the Fairy Lake section.

GRANULIFERELLA PLECTULA
E. J. Zeller, n. sp.
Pl. 77, fig. 18;
Pl. 78, fig. 18,19,21;
Pl. 79, fig. 2

The shell is small, discoidal, involute, and more strongly umbilicate on one side than on the other. The chambers are moderately to strongly swollen between the sutures. The septa are short and show slight to moderate anterior direction. The specimens studied do not show the aperture clearly but it is apparently low and very narrow and is situated at the base of the apertural face. The chamber walls are thick and are composed of a single layer of granular material, probably calcite. Secondary deposits are absent. The coiling is plectogyroid and the total rotational distortion is moderately large. The proloculus is very small and is rarely shown because of poor preservation. Mature shells show one and one-half volutions. The diameter of adult shells varies from 0.2 to 0.3 mm.

Remarks.—Granuliferella plectula differs from *G. granulosa* in its thinner walls, generally smaller size, and in the greater degree of inflation of the chambers. It differs from *G. tumida* in its thicker wall, its greater

angular distortion, its less highly inflated chambers and in its lack of secondary deposits.

Occurrence.—Granuliferella plectula occurs in the lowest beds of the Jo Anna in the South Confusion Range section, the middle portion of the Madison in the Lakeside Mountains section, and the upper part of the Madison in the Blacksmith Fork Canyon section. The holotype comes from the middle of Bed 17 which is approximately 630 feet above the base of the Madison in the Lakeside Mountains section.

GRANULIFERELLA TUMIDA
E. J. Zeller, n. sp.
Pl. 77, fig. 3,21,22;
Pl. 81, fig. 14,15,17,18

The shell is discoidal, involute, and more strongly umbilicate on one side than on the other. The chambers are very large and strongly swollen between the sutures. The septa appear to be secondarily shortened by resorption causing the species to have an unusually high tunnel. The septa are short and show slight anterior direction. The aperture is slit-like and is located at the base of the apertural face. The wall is thin and finely granular. Specimens generally show rudimentary development of secondary deposits which usually occur as irregular thickenings on the posterior surfaces of each of the septa, directly above the tunnel. Many of the specimens studied show evidence of breakage and removal of the final chamber or chambers probably because of the thin chamber walls. The coiling is plectogyroid and perfect specimens show the angular distortion to be moderate. Complete, adult shells show two to two and one-half volutions. The diameter of adult shells averages 0.3 mm.

Remarks.—Granuliferella tumida differs from *G. granulosa* in its much thinner wall, its smaller total angular distortion, its greater number of volutions and in its possession of secondary deposits. In general, this species shows many affinities to some of the

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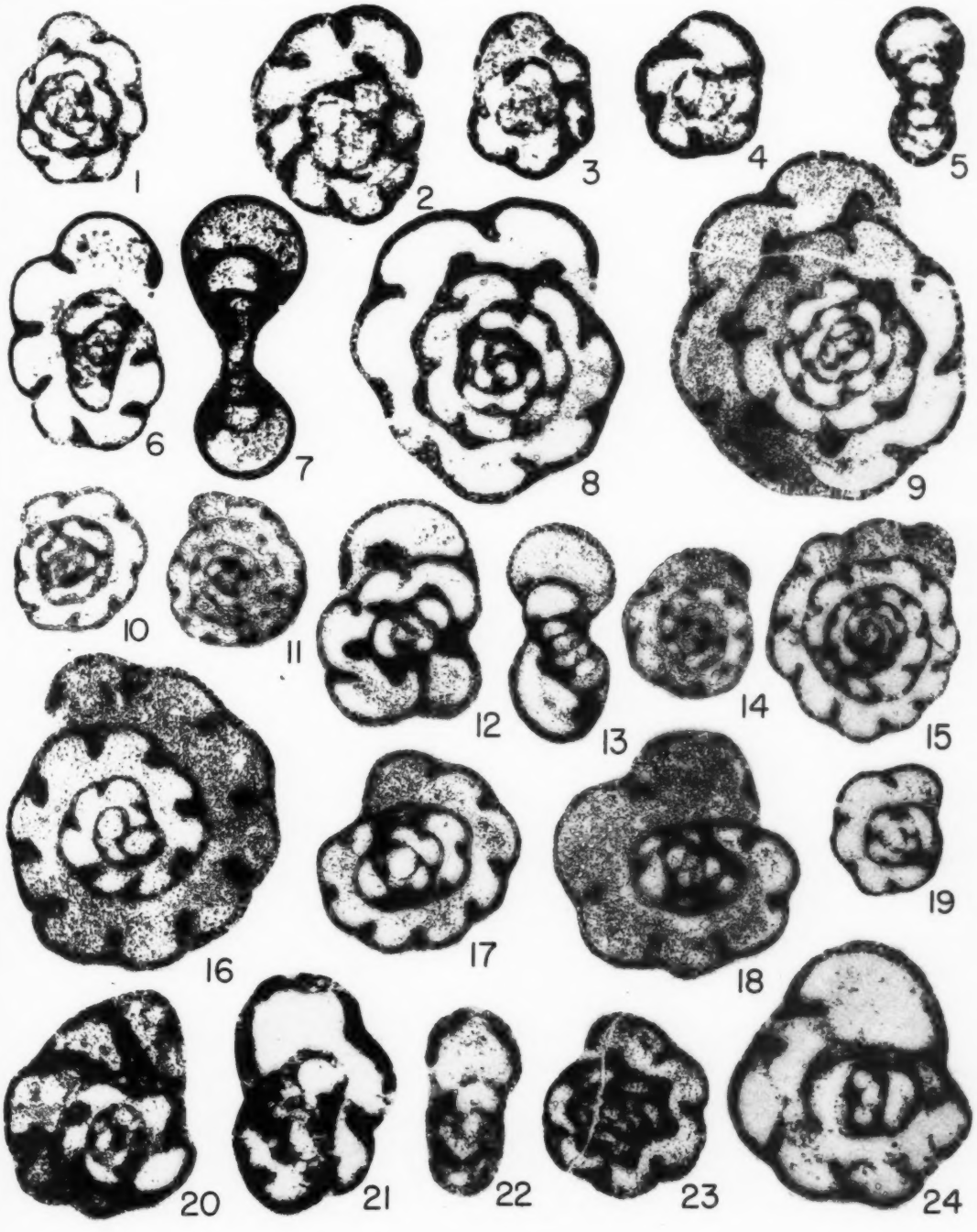
EXPLANATION OF PLATE 79
All figures, ×100

FIG. *1,6,14,19,24—Plectogyra* sp. Horizontal axial sections; *1*, Top Bed 27; *6*, Bed 34; *14,19*, Bed 36; *24*, Bed 37; Blacksmith Fork section.
2—Granuliferella plectula E. J. Zeller, n. sp. Horizontal axial section, Top Bed 27, Blacksmith Fork section.
3,4—Granuliferella granulosa E. J. Zeller, n. sp. Horizontal axial sections, Top Bed 27, Blacksmith Fork section.
5—Granuliferella granulosa E. J. Zeller, n. sp. Vertical axial section, Top Bed 27, Blacksmith Fork section.
7—Plectogyra tumula E. J. Zeller, n. sp. Vertical axial section, Base Bed 29, Blacksmith Fork section.
8,9—Plectogyra tumula E. J. Zeller, n. sp. Horizontal axial sections, Base Bed 29, Blacksmith Fork section; *9* is the holotype.
10—Plectogyra anteflexa E. J. Zeller, n. sp. Horizontal axial section, Bed 36, Blacksmith Fork section.
11—Endothyra taedia E. J. Zeller, n. sp. Sagittal section, Bed 36, Blacksmith Fork section.
12—Plectogyra tumula E. J. Zeller, n. sp. Oblique section, Bed 36, Blacksmith Fork section.
13—Plectogyra sp. Vertical axial, Bed 34, Blacksmith Fork section.
15—Endothyra disca E. J. Zeller, n. sp. Sagittal section of the holotype, Bed 36, Blacksmith Fork section.
16,17—Plectogyra tumesepta E. J. Zeller, n. sp. Horizontal axial sections, Bed 36, Blacksmith Fork section; *16*, is the holotype.
18—Plectogyra inflata E. J. Zeller, n. sp. Horizontal section of the holotype, Bed 36, Blacksmith Fork section.
20,21—Granuliferella granulosa E. J. Zeller, n. sp. Horizontal axial sections, Bed 39, Blacksmith Fork section.
22—Granuliferella granulosa E. J. Zeller, n. sp. Vertical axial section, Bed 39, Blacksmith Fork section.
23—Plectogyra tumula E. J. Zeller, n. sp. Horizontal axial section, Bed 37, Blacksmith Fork section.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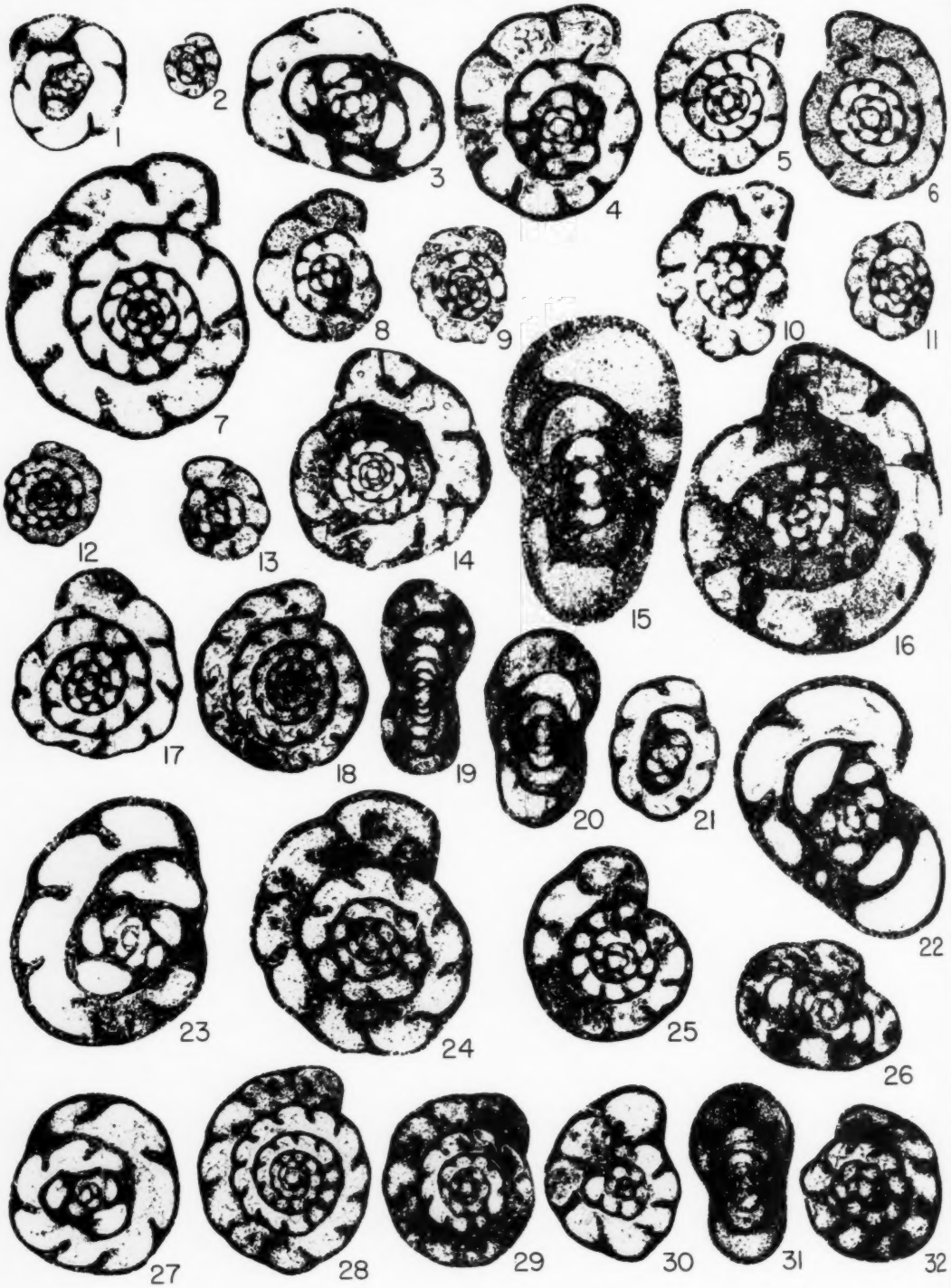
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primitive species of *Plectogyra*. It differs from *Plectogyra* in the coarsely granular nature of its wall.

Occurrence.—*Granuliferella tumida* occurs in the upper Jo Anna in the Bishop Springs section and in the middle and lower Jo Anna in the South Confusion Range section. It is also found in the basal Madison in the South Teton section. The holotype is from the top of Bed 29 approximately 60 feet above the base of the Madison in the South Teton section.

PLECTOGYRA TUMULA E. J. Zeller, n. sp.
Pl. 77, fig. 5,6,11;
Pl. 79, fig. 7,8,9,12,23;
Pl. 82, fig. 3,4,16,17

The shell is discoidal, partially evolute, and umbilicate on both sides. The chambers are of moderate size and are not strongly swollen between the sutures. The proloculus is of moderate size and averages from 20 to 30 microns in diameter. Secondary deposits consist of simple, symmetrical, or slightly asymmetrical, tumuli. These tumuli are situated on the floor of the chambers behind the anteriorly directed septa and they are normally of a height equal to about two-thirds the height of the chamber. The tumuli frequently show little evidence of resorption in the early volutions of the shell and they show their maximum development in the chambers of the last volution. The aperture is low and is situated at the base of the apertural face. The coiling is plectogyroid but the total angular distortion is very small and some specimens appear to be nearly planispiral. Adult shells show three and one-half to five volutions. Mature shells are 0.4 to 0.5 mm. in diameter.

Remarks.—*Plectogyra tumula* differs from *P. plectogyra* in its more highly developed secondary deposits and its much smaller total angular distortion. It differs from *P. trachida* in its larger and more symmetrical secondary deposits and in its smaller total angular distortion.

Occurrence.—*Plectogyra tumula* is a widespread species of relatively short stratigraphic range. It is distinctive and sufficiently abundant that it is useful as a stratigraphic zone marker. *P. tumula* has been found in the middle and upper Jo Anna limestone in the South Confusion Range section in the middle and upper Madison of the Blacksmith Fork Canyon section and in the upper Madison of the Fairy Lake section. The holotype was found in the base of Bed 29 which is approximately 660 feet above the base of the Blacksmith Fork Canyon section.

EXPLANATION OF PLATE 80
All figures, ×75

FIG. *1*—*Plectogyra* sp. Horizontal axial section, Bed 6, Blacksmith Fork section.
2,3,4,8,13,21,23,26,32—*Plectogyra* sp. Horizontal axial sections; *2,3,4,8*, Bed 6; *13*, Bed 12; *21*, Bed 13; *23*, Bed 17; *26,32*, Bed 21; Blacksmith Fork section.
5,17,24,25,29,30—*Endothyra* sp. Sagittal sections; *5*, Bed 6; *17*, Bed 13; *24,25*, Bed 17; *29,30*, Bed 22; Blacksmith Fork section.
6—*Endothyra symmetrica* E. J. Zeller, n. sp. Sagittal section, Bed 6, Blacksmith Fork section.
7,14—*Endothyra macra* E. J. Zeller, n. sp. Sagittal sections, holotype, Bed 8, Blacksmith Fork section; *7* is the holotype.
9—*Endothyra disca* E. J. Zeller, n. sp. Sagittal section, Bed 9, Blacksmith Fork section.
10,11—*Plectogyra* sp. Horizontal axial sections, Bed 8, Blacksmith Fork section.
12—*Endothyra taedia* E. J. Zeller, n. sp. Sagittal section, Bed 12, Blacksmith Fork section.
16—*Endothyra utahensis* E. J. Zeller, n. sp. Sagittal section of the holotype, Bed 9, Blacksmith Fork section.
15—*Endothyra utahensis* E. J. Zeller, n. sp. Axial section, Bed 9, Blacksmith Fork section.
18—*Endothyra spiroides* E. J. Zeller, n. sp. Sagittal section, Bed 13, Blacksmith Fork section.
19—*Endothyra spiroides* E. J. Zeller, n. sp. Axial section, Bed 13, Blacksmith Fork section.
20—*Endothyra* sp. Axial section, Bed 13, Blacksmith Fork section.
22—*Plectogyra* sp. Oblique section, Bed 14, Blacksmith Fork section.
27—*Plectogyra torquida* E. J. Zeller, n. sp. Horizontal axial section, Bed 22, Blacksmith Fork section.
28—*Endothyra spiroides* E. J. Zeller, n. sp. Sagittal section of the holotype, Bed 22, Blacksmith Fork section.
31—*Endothyra* sp. Axial section, Bed 22, Blacksmith Fork section.

PLECTOGYRA ANTEFLEXA
E. J. Zeller, n. sp.
Pl. 79, fig. 10;
Pl. 81, fig. 6,11,12;
Pl. 82, fig. 8.9,10,11,12

The shell is discoidal, almost completely involute, and shows a shallow umbilicus on one side only. The chambers are low and their roof wall is asymmetrical. The septa are short and have a very strong anterior direction. The proloculus is of moderate size and averages 20 to 30 microns in diameter. Secondary deposits are poorly developed or lacking. When specimens do show secondary deposits they consist of very low tumuli. The aperture is low and slit-like and is situated at the base of the apertural face. The coiling is plectogyroid and the total angular distortion is small. Mature shells show three to four volutions and have a diameter of 0.3 to 0.4 mm.

Remarks.—Plectogyra anteflexa differs from *P. trachida* in its smaller size, its general lack of secondary deposits, and its smaller total rotational distortion. The distinctive shape of the chamber roof as seen in horizontal axial sections serves to distinguish this species from most other species.

Occurrence.—Plectogyra anteflexa has been found in the middle beds of the Madison formation in the Blacksmith Fork Canyon section, the South Teton section, and the Fairy Lake section. The holotype comes from the base of Bed 31 which is 143 feet above the base of the Madison in the South Teton section. *P. anteflexa* appears to be confined to the lower half of the *P. tumula* zone.

PLECTOGYRA TRACHIDA E. J. Zeller, n. sp.
Pl. 81, fig. 1

The shell is discoidal and probably umbilicate on one side only. The chambers are short but high. The septa are of medium length and show a strong anterior direction. The proloculus is small and indistinct in the holotype. The secondary deposits consist of low acanthi which show a slight anterior direction. Resorption causes rounding of the acanthi in the earlier chambers giving them the appearance of low tumuli. The total angular distortion of the plectogyroid coiling is moderately large. The aperture is slit-like, at the base of the apertural face. The mature shell shows four and one-half volutions and is 0.5 mm. in diameter.

Remarks.—Plectogyra trachida differs from *P. tumula* in its larger total angular distortion and in its smaller, less uniformly distributed secondary deposits. *P. trachida* differs from *P. anteflexa* in its higher and shorter chambers, its development of secondary deposits, and its larger degree of angular distortion.

Occurrence.—Plectogyra trachida is found in the uppermost beds of the Madison in the South Teton section. The holotype is from the base of Bed 35, which is 618 feet above the base of the Madison.

PLECTOGYRA TUMESEPTA E. J. Zeller, n.sp.
Pl. 79, fig. 16,17

The shell is discoidal and more strongly umbilicate on one side than on the other. The chambers are short and high but are not strongly swollen between the sutures. The proloculus is moderately large and is 40 microns in diameter. Secondary deposits consist of prominent thickenings on the posterior sides of each of the septa. No secondary deposits are present on the floor of the chambers. The coiling is plectogyroid but the angular distortion is very small. Mature shells show two and one-half to three volutions and are 0.4 mm. in diameter.

Remarks.—Plectogyra tumesepta differs from *P. tumula* in its complete lack of secondary deposits on the floor of the chambers and in the presence of septal thickenings on the posterior sides of the septa. *P. tumesepta* differs from *P. inflata* in its smaller, less inflated chambers and in its much smaller total angular distortion.

Occurrence.—Plectogyra tumesepta is found in the middle of the Madison in the Blacksmith Fork Canyon section. The holotype is from Bed 36 which is approximately 320 feet above the base of the Madison.

PLECTOGYRA TORQUIDA E. J. Zeller n. sp.
Pl. 75, fig. 33; Pl. 78, fig. 7; Pl. 80,fig. 27

The shell is discoidal, partially evolute, and umbilicate on one side only. The chambers are somewhat swollen between the sutures and the septa are of medium length and have a strong anterior direction. The proloculus is of medium size and is about 35 microns in diameter. Secondary deposits are

not strongly developed but there is usually a single hamulus in the final chamber. The bases of resorbed hamuli sometimes remain in the earlier chambers. The aperture is very low and there is strong evidence of resorption of the septal ends resulting in increased tunnel height. The coiling is plectogyroid showing moderate angular distortion. Adult shells show three to three and one-half volutions. The diameter of mature shells is .35 to .45 mm.

Remarks.—Plectogyra torquida differs from *P. plectogyra* in its less well-developed secondary deposits and its less inflated chambers.

Occurrence.—Plectogyra torquida is present in the Meramecian rocks of the Cordilleran area. It occurs in the top of the Redwall limestone of the Havasu Canyon section and in the middle of the Brazer in the Lakeside Mountains section. It is also present in the lower portion of the Brazer limestone in the Blacksmith Fork Canyon section. The holotype is from the base of Bed 23 which is 185 feet above the base of the Brazer in the Lakeside Mountains section.

PLECTOGYRA RUGOSA E. J. Zeller, n. sp.
Pl. 78, fig. 3,4

The shell is discoidal, involute, and umbilicate on one side only. The chambers are only slightly swollen between the sutures. The septa are long and the tunnel is low. The septa show moderate anterior direction. The proloculus is small, being only 20 microns in diameter. The secondary deposits consist of tumuli and connecting deposits on the floor of the chambers. Some of the septa show thin deposits on their posterior surfaces. The aperture appears to be somewhat higher and wider than it is in most other species of *Plectogyra*. The coiling is plectogyroid and shows medium total angular distortion. There are three volutions in adult shells. Mature shells are 0.4 to 0.5 mm. in diameter.

Remarks.—Plectogyra rugosa differs from *P. irregularis* in its larger size, its thicker wall, its less inflated chambers, and its smaller total angular distortion. It differs from *P. phrissa* in its smaller proportional chamber size and in its thinner connecting deposits between tumuli.

Occurrence.—Plectogyra rugosa is considered to be Lower Meramecian in age although it is possible that forms resembling it closely may make their appearance in the Upper Osagian. All of the specimens including the holotype came from Bed 1 at the base of the South Cedar Mountains section. The Mississippian limestone in this area has not been studied in detail but it would appear to correlate with the Brazer.

PLECTOGYRA IRREGULARIS E. J. Zeller, n. sp.
Pl. 78, fig. 6,12,13,14,15

The shell is discoidal, involute, and umbilicate on one side only. The chambers are strongly swollen between the sutures. The walls of this species are unusually thin and appear to be structurally weak so that shells are often partially crushed. The septa in perfect specimens are not strongly anteriorly directed. The proloculus is minute averaging between 15 and 20 microns in diameter. Secondary deposits consist of tumuli or blunt acanthi which are connected at their bases by massive connecting deposits on the floor of the chambers. Some specimens show thin deposits on the posterior surfaces of the septa. The specimens studied possess apertures which are higher and wider than the apertures of most other species. Coiling is plectogyroid and the total angular distortion is large. Mature shells have approximately three volutions and are about .25 mm. in diameter.

Remarks.—The extreme thinness of the chamber walls is the most prominent characteristic of *Plectogyra irregularis* and separates it from most other species. It differs from *P. rugosa* in its thinner walls, its heavier connecting deposits on the floor of the chambers, and in its smaller size.

Occurrence.—Plectogyra irregularis is found in the upper part of the Brazer limestone in the Lakeside Mountains section. The holotype is from the base of Bed 23 which is 185 feet above the base of the Brazer in the Lakeside Mountains section.

PLECTOGYRA INFLATA E. J. Zeller, n. sp.
Pl. 79, fig. 18

The shell is discoidal, involute, and umbilicate on one side only. The chambers are strongly swollen between the sutures and the septa are short, showing only very slight anterior direction. The chamber walls are

very thin. The proloculus is not well known in the holotype but is probably small. Secondary deposits are limited to thickenings on the posterior surfaces of the septa. The aperture is low and slit-like. The coiling is plectogyroid and the total angular distortion is moderately large. There are three to three and one-half volutions in the adult shell. The diameter of the shell is .35 mm.

Remarks.—Plectogyra inflata differs from *P. irregularis* in its lack of secondary deposits on the floor of the chambers. It differs from *P. tumesepta* in its more highly inflated chambers and in its greater total angular distortion.

Occurrence.—Plectogyra inflata is found in the middle of the Madison in the Blacksmith Fork Canyon section. The holotype is from Bed 36 which is approximately 320 feet above the base of the Madison in Blacksmith Fork Canyon.

PLECTOGYRA NEVADAENSIS E. J. Zeller, n. sp.
Pl. 76, fig. 3

The shell is discoidal, partially evolute. and umbilicate on one side only. The chambers are only slightly swollen between the sutures and the walls are thick. The septa are of medium length and show moderate anterior direction. The proloculus is very large, having a diameter of 55 microns. Secondary deposits are not clearly shown by the specimens studied because the preservation is poor. A low hamulus may be present in the final chamber. The aperture appears to be low. The coiling is plectogyroid and the total angular distortion is medium. Three volutions are present in the adult shell and the diameter is approximately 0.5 mm.

Remarks.—Plectogyra nevadaensis differs from *P. torquida* in its smaller total angular distortion, its thicker walls, and its larger proloculus. It differs from *P. plectogyra* in its larger proloculus, its thicker walls and its shorter, less inflated chambers.

Occurrence.—Plectogyra nevadaensis is found in the middle of the Redwall limestone in the South Muddy Mountain section. The holotype is from the middle of Bed 25 which is 505 feet above the base of the Redwall in the South Muddy Mountain section. This species has strong affinities to some of the large forms present in the Lower Meramecian of the Mississippi Valley area.

ENDOTHYRA TAEDIA E. J. Zeller, n. sp.
Pl. 79, fig. 11; Pl. 80, fig. 12

The shell is discoidal, probably partially evolute, and the chambers are very slightly swollen between the sutures. The septa are very short, showing much resorption of the septal ends. The proloculus is minute but poor preservation prevents accurate measurement. The diameter of the proloculus is apparently between 10 and 20 microns. The aperture is low and slit-like at the base of

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EXPLANATION OF PLATE 81

All figures, ×100

FIG. *1—Plectogyra trachida* E. J. Zeller, n. sp. Horizontal axial section of the holotype showing shape of chambers and secondary deposits, Base Bed 35, South Teton section.

2,3,9,13—Plectogyra sp. Oblique sections; *2,3*, Base Bed 35; *9,13*, Base Bed 31; South Teton section.

4,5,7,8,10—Granuliferella granulosa E. J. Zeller, n. sp. Horizontal axial sections showing the thick, coarsely granular wall, Base Bed 35, South Teton section.

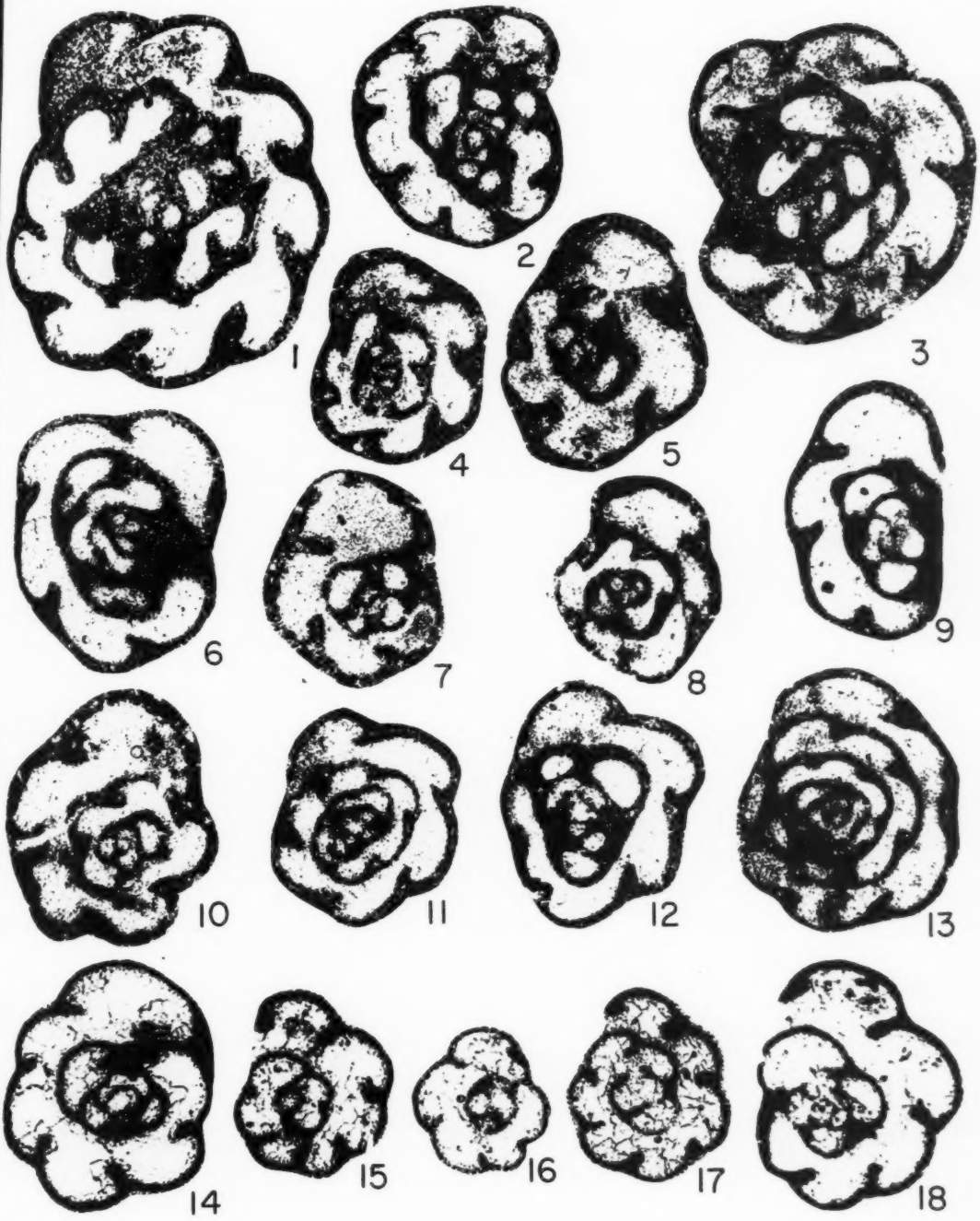
6,12—Plectogyra anteflexa E. J. Zeller, n. sp. Horizontal axial sections showing the strong anterior direction of the septa, Base Bed 31, South Teton section.

11—Plectogyra anteflexa E. J. Zeller, n. sp. Horizontal axial section of the holotype showing the shape of the chambers and the low total angular distortion, Base Bed 31, South Teton section.

14,15,17—Granuliferella tumida E. J. Zeller, n. sp. Horizontal axial sections, Top Bed 29, South Teton section.

16—Granuliferella sp. Horizontal axial section, Top Bed 29, South Teton section.

18—Granuliferella tumida E. J. Zeller, n. sp. Horizontal axial section of the holotype showing the inflated nature of the chambers, Top Bed 29, South Teton section.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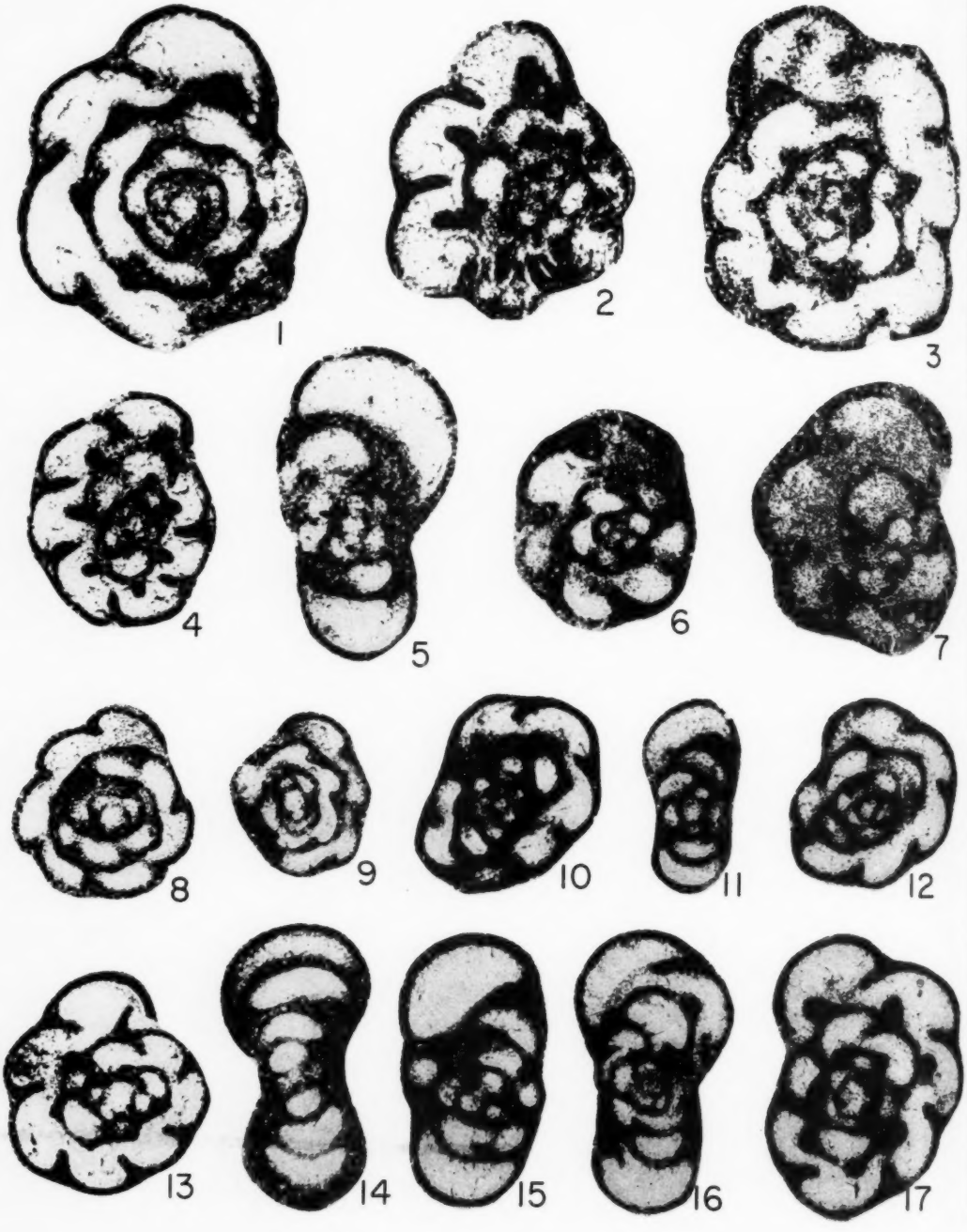
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the apertural face. Coiling is planispiral with a slight tendency to irregularity in the early volutions. The septal count from the first to the third volution is 6, 9, 13, respectively. The coiling shows a very slow rate of expansion. The adult shell is 0.2 mm. in diameter.

Remarks.—Endothyra taedia differs from *E. disca* in its smaller size, shorter and more numerous septa, and its less rapid rate of expansion of coiling.

Occurrence.—Endothyra taedia is a long-ranging species which is present in rocks of both Lower and Upper Mississippian. It is present in the Middle and Upper Madison and in the Upper Brazer of the Blacksmith Fork Canyon section. The holotype is from Bed 36 which is approximately 320 feet above the base of the Madison in the Blacksmith Fork Canyon section.

ENDOTHYRA DISCA E. J. Zeller, n. sp.
Pl. 79, fig. 15; Pl. 80, fig. 9

The shell is discoidal, probably partially evolute, and the chambers are moderately swollen between the sutures. The septa are long and they show a strong anterior direction. The coiling is planispiral but shows slight irregularity. Secondary deposits are absent. The proloculus is very small, about 10 microns in diameter. The septal count from the first to the third volution is 6, 8, 10, respectively. The coiling shows a slow rate of expansion. The adult shells average 0.3 mm. in diameter.

Remarks.—Endothyra disca differs from *E. taedia* in its larger size, its longer and less numerous septa, and its more rapid rate of expansion.

Occurrence.—Endothyra disca is present in the middle of the Madison and in the upper portion of the Brazer limestone in the Blacksmith Fork Canyon section. The holotype is from Bed 36 which is approximately 320 feet above the base of the Madison in the Blacksmith Fork Canyon section.

ENDOTHYRA SYMMETRICA E. J. Zeller, n. sp.
Pl. 75, fig. 14,18,19; Pl. 78, fig. 8,9; Pl. 80, fig. 6

The shell is discoidal, involute, and the chambers are only slightly swollen between the sutures. The coiling is planispiral. The septa are moderately long and show only slight anterior direction. The proloculus is approximately 30 microns in diameter. Secondary deposits are confined to the development of a prominent hamulus in the final chamber. Traces of thin secondary deposits are sometimes present on the floor of the chambers. The septal count from the first to the fourth volution is 7, 8, 10, 11, respectively. The coiling shows a medium rate of expansion. Adult shells average 0.4 mm. in diameter.

Remarks.—Endothyra symmetrica differs from *E. spiroides* in the more rapid rate of expansion of the shell coiling and in its fewer volutions and less numerous septa. *E. symmetrica* differs from *E. macra* in its smaller size and more regular rate of expansion of the shell coiling.

Occurrence.—Endothyra symmetrica is a widespread species of limited stratigraphic range. Its stratigraphic restriction and readily recognized form make it useful as a zone marker in the Mississippian of the Cordilleran Region. It shows strong similarities to forms in the Upper Meramecian of the Mississippi Valley type section but it may range upward into Chesteran rocks in

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EXPLANATION OF PLATE 82
All figures, ×100

FIG. *1,2,13—Plectogyra* sp. Horizontal axial sections; *1,2*, Bed 8; *13*, Bed 5; Fairy Lake section.
3,4—Plectogyra tumula E. J. Zeller, n. sp. Horizontal axial sections, Bed 8, Fairy Lake Section.
5,14,15—Plectogyra sp. Vertical axial section; *5*, Bed 7, *14,15*, Bed 5; Fairy Lake section.
6,7—Granuliferella granulosa E. J. Zeller, n. sp. Horizontal axial sections, Bed 7, Fairy Lake section; *6* is the holotype.
8,9,12—Plectogyra anteflexa E. J. Zeller, n. sp. Horizontal axial sections; *8,9*, Bed 6; *12*, Bed 5; Fairy Lake section.
10—Plectogyra anteflexa E. J. Zeller, n. sp. Oblique section, Bed 7, Fairy Lake section.
11—Plectogyra anteflexa E. J. Zeller, n. sp. Vertical axial section, Bed 7, Fairy Lake section.
16,17—Plectogyra tumula E. J. Zeller, n. sp. Oblique sections, Bed 5, Fairy Lake section.

the Cordilleran Region. Specimens of *E. symmetrica* have been found in the upper Escabrosa in the Chiricahua Mountain section, in the upper part of the South Cedar Mountains section, and in the upper part of the Brazer limestone in both the Lakeside Mountains section and the Blacksmith Fork Canyon section. The holotype is from Bed 9 which is 273 feet above the base of the Escabrosa limestone in the Chiricahua Mountain section.

ENDOTHYRA SPIROIDES E. J. Zeller, n. sp.
Pl. 75, fig. 25; Pl. 76, fig. 6,7,8; Pl. 80, fig. 18,19,28

The shell is discoidal, involute, and the chambers show almost no swelling between the sutures. The septa are of medium length and they show moderate anterior direction. The proloculus is about 20 microns in diameter. Secondary deposits are present in the form of a single small hamulus which is present in the last chamber. The septal count from the first to the fifth volution is 7, 8, 11, 12, 11, respectively. The coiling shows a slow rate of expansion. Adult shells average between 0.3 and 0.4 mm. in diameter.

Remarks.—Endothyra spiroides differs from *E. symmetrica* in its greater number of volutions, its less rapid rate of shell expansion, and its more numerous septa.

Occurrence.—Endothyra spiroides is a widespread species which is apparently confined to rocks of Lower Meramecian age. It appears to be identical to forms present in the Salem formation of the Mississippi Valley area. Its stratigraphic restriction makes it a valuable zone marker in the Cordilleran region. It is present in the upper part of the Redwall in the Havasu Canyon section, in the upper Redwall in the South Muddy Mountain section, and in the middle and lower Brazer of the Blacksmith Fork Canyon section. The holotype is from Bed 22 which is within the Brazer limestone, approximately 1,010 feet above the top of the Madison in the Blacksmith Fork Canyon section.

ENDOTHYRA UTAHENSIS E. J. Zeller n. sp.
Pl. 80, fig. 15,16

The shell is discoidal, involute, and the chambers are only slightly swollen between the sutures. The septa are of medium length, showing moderate anterior direction. The coiling is essentially planispiral but it shows slight irregularity. The proloculus is approximately 40 microns in diameter. Secondary deposits are confined to a single large hamulus in the final chamber. The septal count from the first to the fourth volution is 7, 7, 9, 8, respectively. Mature shells are from 0.5 to 0.6 mm. in diameter. The shell shows an irregular rate of expansion of the coil.

Remarks.—Endothyra utahensis differs from *E. symmetrica* in its larger size and in the fewer and larger chambers in the adult portion of the shell.

Occurrence.—Endothyra utahensis is present in the upper Brazer of the Blacksmith Fork Canyon section. The holotype is from Bed 9 which is within the Brazer limestone, approximately 1,586 feet above the top of the Madison in the Blacksmith Fork Canyon section.

ENDOTHYRA MACRA E. J. Zeller, n. sp.
Pl. 80, fig. 7,14

The shell is discoidal, involute, and the chambers are slightly swollen between the sutures. The septa are long and show medium anterior direction. The coiling is planispiral. The proloculus is about 15 microns in diameter. A single large hamulus present in the final chamber is the only form of secondary deposit shown by this species. The septal count from the first to the fourth volution is 6, 8, 10, 11, respectively. The first two volutions of the shell are much more tightly coiled than the succeeding volutions. The sharp change in rate of shell expansion is especially characteristic of this species.

Remarks.—Endothyra macra differs from *E. utahensis* in its more numerous septa and in the change in coiling of the shell from the juvenile portion to the adult. It differs from *E. symmetrica* in its larger size, smaller proloculus and in the change in shell coiling from the juvenile portion to the adult.

Occurrence.—Endothyra macra occurs in the upper Brazer in the Blacksmith Fork Canyon section. The holotype is from Bed 8 which is within the Brazer limestone, approximately 1,615 feet above the top of the Madison in the Blacksmith Fork Canyon section.

TABLE 1.—MEASUREMENTS OF *Paramillerella tortula*, IN MILLIMETERS

Figure	Septal Count				Prol. Diam.	Length	Width
	1	2	3	4			
4	—	8	11	—	.023	—	.27
5	—	—	—	—	.025	.08	.24
6	7	10	12	—	.024	—	.20
7	7	10	11	13	.022	—	.30
8	6	9	10	13	.020	—	.29
10	—	10	11	—	—	—	.23
11	—	10	11	—	—	—	.24
12	—	—	—	—	.020	.09	.30

TABLE I—(*continued*)

Figure	Ratio	1	2	3	4	5	Wall Thickness
4	—	.014	.019	.025	.033	.047	.008
5	1:.30	.016	.030	.032	.031	—	.008
6	—	.019	.023	.026	.038	—	.006
7	—	.014	.026	.036	.046	—	.006
8	—	.011	.014	.030	.044	.048	.008
10	—	.011	.022	.034	.037	—	.006
11	—	.016	.022	.035	.046	—	.008
12	1:.30	.016	.024	.031	.043	.050	.006

Figures refer to specimens on Plate 75.

PARAMILLERELLA TORTULA, D. Zeller
Pl. 75, fig. 4,5,6,7,8,10,11,12

Millerella tortula D. ZELLER, 1953, Jour. Paleont., vol. 27, no. 2, p. 182–199.

The shell is discoidal and partially evolute with a broadly rounded periphery. The proloculus is minute and the juvenarium is plectogyroid, causing elongation of the shell in some specimens. The walls are of moderate thickness and the septa show slight anterior direction. Secondary deposits are sparse and irregularly distributed. They are present as low chomata. Data on shell measurements and septal counts are included in Table 1.

Remarks.—Millerella tortula was originally described by D. Zeller (1953) from the Glen Dean limestone of Kentucky.

SUMMARY

Twelve stratigraphic sections have been measured and sampled in the area of the Cordilleran geosyncline. These sections contain abundant endothyroid foraminifers and a stratigraphic zonation is here proposed based upon these foraminifers. Eighteen new species of endothyroid foraminifers are described, including three new species of a new genus, *Granuliferella*, six new species of *Endothyra*, and nine new species of *Plectogyra*.

Through the use of endothyroid foraminifers it is possible to divide the Mississippian into five distinct faunal zones. These zones include the *Granuliferella* zone and the *Plectogyra tumula* zone at the top of the beds which are correlated with the Madison formation of the Cordilleran Region. Beds of Meramecian age are usually separated from the underlying Madison either by an unconformity or by intervening sediments which do not contain foraminifers. The Meramecian sediments can also be divided into two zones, the *Endothyra spiroides* zone below and the *Endothyra symmetrica* zone above. Rocks showing the typical midcontinent Chesteran facies are present in only one of the stratigraphic sections studied. These rocks and the uppermost rocks in the Mississippian of central Utah contain the primitive fusulinid *Paramillerella*. Even though the genus *Paramillerella* crosses the boundary between the Mississippian and Pennsylvanian it still appears to be the most useful foraminifer for the positive identification of Chesteran rocks.

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PERMIAN AMMONOIDS FROM TUNISIA

A. K. MILLER AND W. M. FURNISH
State University of Iowa, Iowa City, Iowa

ABSTRACT—Representatives of *Agathiceras*, *Popanoceras*, *Peritrochia*, *Stacheoceras*, and *Cibolites* are illustrated and described from the 5000-foot Permian section in the Djebel Tebaga area near Médenine in southern Tunisia; *Pseudogastrioceras*, *Strigogoniatites*, and *Medlicottia* have also been cited from this locality. These ammonoids indicate that the containing beds are late Middle Permian in age and that their fauna is closely related to that of the classic Sicilian Sosio limestones.

THE only marine Permian strata known from northern Africa are exposed at Djebel Tebaga west of Médenine, some 50 km. (30 mi.) south of Gabès, near the foot of the mountains of Matmata in southern Tunisia. They consist of some 1700 m. (5000 ft.) of steeply dipping sandstones, shales, and carbonates exposed on the southern flank of an anticline. These Permian beds are overlain unconformably by Triassic sediments and are overlapped by nearly horizontal later Mesozoic. Their fauna is varied and consists of land plants, fusulinids, corals, echinoderms, bryozoans, and brachiopods, as well as mollusks (including a few ammonoids).

The discovery of these late Paleozoic strata was made in 1932 by Eugène Berkaloff, and early the following year, in collaboration with Henri Douvillé & Marcel Solignac, he published a brief description of the rocks and listed the fossils they had yielded. A more detailed account of the stratigraphy was issued in 1934 by Solignac & Berkaloff, together with a study of the contained fusulinids by Douvillé and of the crinoids by Aurélien Valette. In 1940 Gilbert Mathieu mentioned the section, in 1947 (together with Raymond Ciry) he discussed the faunal sequence briefly, and in 1950 he published a report on the stratigraphy.

According to Solignac & Berkaloff (1934, p. 9–14), the Permian section, from bottom to top, consists of the following stratigraphic units: (1) 2–3 m. of siliceous limestone, (2) 135 m. of varicolored sandstones with *Neoschwagerina* and *Medlicottia*, (3) 160–180 m. of green marls and limestones with an abundant and varied fauna, (4) 60 m. of siliceous limestones, (5) 450 m. of poorly exposed marls, sandstones, and limestones containing *Neoschwagerina* and bellerophontids, (6) 120 m. of green marls and limestones with calcareous sandstones, containing *Neoschwagerina*, (7) 50 m. of siliceous mineralized limestones [forming the central crest of Djebel Tebaga], (8) conglomerate, (9) 40 m. of varicolored extremely fossiliferous sandstones containing bellerophontids and *Strigogoniatites*, (10) 60 m. of fossiliferous yellow and red sandstones and marls, (11) 80 m. of brown cross-bedded sandstones, and (12) 60 m. of sandstones and marls. The immediately overlying sandstones are believed to represent the Triassic.

Some of the specimens we are studying have not been placed in Solignac & Berkaloff's stratigraphic section. Most of them have been labeled in accordance with Mathieu's numbered units, which can be correlated with the section we have listed by comparing the geologic maps, cross sections, and lithologic descriptions in the two reports. The upper part of the Baten Beni Zid sandstone (unit 3 of Solignac & Berkaloff) has yielded a new species of *Cibolites*. From higher in the section, in the Bellerophon limestone of Mathieu (above unit 8 of Solignac & Berkaloff), we have representatives of *Agathiceras*, *Popanoceras*, *Peritrochia*, and probably *Stacheoceras*. None of the ammonoids known from Tunisia came from the basal or the uppermost part of the section, and they should perhaps be regarded as representing a single fauna.

All the available evidence seems to be compatible with a late Middle Permian (early Guadalupian) age assignment for this fauna, a conclusion that is based primarily on the similarity of the Tunisian ammonoids with those of the Sosio limestones of Sicily, some 350 miles to the northeast. Those limestones have yielded a large variety of

Permian ammonoids (some 70 species representing about 25 genera), and therefore it is not surprising that one can find among them 3 counterparts of all the relatively few forms known from Tunisia. Accordingly, the close relationship between the two assemblages may be more apparent than real.

Representatives of the stable genus *Agathiceras* are ubiquitous and are locally abundant. Forms that can scarcely be distinguished specifically occur in Middle and Upper Pennsylvanian and in Lower and Middle Permian. The presence of this genus in Tunisia is a reason for regarding the fauna as Middle rather than Upper Permian—no Upper Permian species have been recorded.

Popanoceras is likewise of widespread occurrence, and it is confined to the Lower and Middle Permian. The single specimen known from Tunisia is referable to a Sicilian species, *P. multistriatum*, which, however, is not diagnostic of precise age.

The genus *Peritrochia* is common in the late Paleozoic at a number of horizons and localities. However, the species with which we are concerned, *P. darae*, is fairly distinctive, and the fact that it occurs in both the Sicilian and Tunisian Permian is probably significant. Nevertheless, comparable older forms have been described from the Bitauni beds of Timor, the Bone Springs Limestone of West Texas, and the Phosphoria Formation of Wyoming.

Stacheoceras, a relative of *Peritrochia*, is represented in the available collection by an excellent specimen of *S. mediterraneum*, and a poorly preserved individual which may belong in the similar *S. globosum*. Both of these species were originally described from Sicily, so they tend to confirm the correlation of the strata there with those in Tunisia. Nevertheless, they can scarcely be said to establish contemporaneity as similar forms occur elsewhere in Middle and Upper Permian.

The Tunisian paraceltitid we are describing as a new species, *Cibolites africanus*, belongs in a significant Permo-Triassic taxon. Congeneric forms occur in the middle Guadalupian of North America, but not elsewhere. In the Middle and Upper Permian, these ammonoids are relatively unstable, and a single small specimen is, therefore, of somewhat questionable value.

The medlicottiids and gastrioceratids that have been listed from this fauna are not available to us for study. However, these families are not particularly diagnostic, and, accordingly, a detailed study of the specimens would probably not contribute materially to an understanding of the age relationships of the assemblage.

Fusulinids occur in Tunisia in association with ammonoids. They are referable to the genera *Dunbarula*, *Parafusulina*, *Neoschwagerina*, and *Yabeina*, and collectively they are representative of the "Tethyan" faunal assemblage. According to Thompson (1948, p. 25) the "Zone of *Yabeina*" has yielded the youngest fusulinids of the Eastern Hemisphere, and Skinner & Wilde (1955) have recorded it from the uppermost Guadalupian, the Lamar Limestone at the top of the marine Permian sequence in West Texas. *Parafusulina* characterizes the Middle Permian of the Western Hemisphere; its stratigraphic range in Eurasia is not so well known but may be somewhat more extensive (Thompson, 1948, p. 55). The Tethyan "Zone of *Verbeekina-Neoschwagerina*" is believed to be late Middle Permian (early Guadalupian) in age, and typical representatives of it are known from the Sosio limestones. Furthermore, *Dunbarula* is associated with the zonal genera in the State of Washington (Thompson, 1954, p. 7–8). It is difficult to collate all of these facts, but it seems reasonable to conclude that the fusulinids are compatible with a correlation of the Sicilian Permian and at least part of the Tunisian section.

It should probably be noted, that Castany (1953, p. 13) mentions a coal test drilled in the center of the anticline where these Permian strata are exposed. At a depth of about 500 meters a fauna of brachiopods was found; Delépine studied it and concluded that it may be Uralian in age. Some 300 meters lower the drill encountered a complex of shales with fusulinds, marls, fine clastic sediments, and breccias. Recently, a 4000-meter test was drilled on the same structure. The well location was on the north flank of the Permian area in the overlapping Jurassic at the surface. The monotonous marl and shale section encountered is believed to be of Permian age to total depth.

For certain of the specimens upon which this report is based, we are indebted to Drs. R. A. Bramkamp and R. E. King, who visited the Djebel Tebaga Permian on an excursion of the Nineteenth International Geological Congress, 1952. Additional material was loaned by Monsignor Gaston Delépine of Lille and Professor Henri Termier of Alger. The photographs which accompany this study were retouched by Dr. Frederick Leach, now of Ohio University.

SYSTEMATIC PALEONTOLOGY

AGATHICERAS SUESSI Gemmellaro
Pl. 83, fig. 9,10

Agathiceras suessi GEMMELLARO, 1887, Gior. Sci. nat. ed econ., t. 19, p. 75,77–78, pl. 6, fig. 1–4; pl. 7, fig. 36; ——, 1888, ibid., t. 20, p. 28–29, pl. C, fig. 20; pl. D, fig. 13; KARPINSKY, 1889, Acad. Imp. Sci. St.-Pétersbourg, Mém., 7e sér., t. 37, no. 2, p. 64,85,88,91; HAUG, 1898, Soc. Géol. France, Mém., Paléont., t. 7, no. 18, p. 33; SMITH, 1903, U. S. Geol. Surv. Mon. 42, p. 105,131; HANIEL, 1915, Paläont. von Timor, Lief. 3, Abh. 6, p. 68,71,72,73; BÖSE, 1919 [1917], Texas Univ. Bull. 1762, p. 115,117,122, 125,194; DIENER, 1921, Fossilium Catalogus, I, Animalia, pars 14, p. 19; SCHINDEWOLF, 1931, Preuss. Geol. Landesanst., Sitzungsbericht, Heft 6, p. 198; BÖHMERS, 1936, Bau und Struktur von Schale und Sipho bei permischen Ammonoidea, p. 70,71; MILLER & FURNISH, 1939, Palaeont. Zeitschr., Bd. 21, p. 298, text-fig. 1C, 1D; ——, 1940, Geol. Soc. Amer., Spec. Pap. 26, p. 118,120, pl. 31, fig. 8–12; ——, 1957, Treatise on invertebrate paleontology, Ammonoidea, p. L51, text-fig. 57.

Adrianites Suessi MOJSISOVICS, 1888, Acad. Imp. Sci. St.-Pétersbourg, Mém., 7e sér., t. 36, no. 5, p. 19.

The representative of this species that we are illustrating was collected in 1952 by Dr. Robert E. King, who donated it to us. It is a limonitic internal mold of the adapical half-volution of the body chamber. Its maximum overall dimension is a little more than 10 mm., and its corresponding width of conch about 6 mm.

Adapically the specimen is bounded by a septum which shows the general shape of the suture. The ensemble of the characters of this individual serves to establish its identity with the common form in the Permian of the Sosio Valley, *A. suessi*.

Occurrence.—Middle Permian "Bellerophon limestone" of the Djebel Tebaga area, Tunisia (stratigraphic unit 3 of Mathieu, 1949, p. 14).

Respository.—State University of Iowa, 8297.

POPANOCERAS MULTISTRIATUM Gemmellaro
Pl. 83, fig. 7,8

Popanoceras multistriatum GEMMELLARO, 1887, Gior. Sci. nat. ed econ., t. 19, p. 19–20, pl. 3, fig. 1–5; pl. 7, fig. 31,32.

Several years ago Professor Henri and Madame Geneviève Termier visited Djebel Tebaga and collected two Permian ammonoids there, which they kindly loaned us for study. One of these is a complete limonitic internal mold of a phragmocone, about 16 mm. in diameter and with a maximum width of conch of some 6 mm. Its umbilicus is virtually closed. On the flattened lateral zones of the specimen, there are slightly sinuous transverse ridges; these are much less prominent than those illustrated by Gemmellaro, presumably because they are on the internal mold, whereas the types preserve the exterior of the test. The external suture of this Tunisian individual consists of a prominently divided ventral lobe, on either side of it seven digitate lateral and auxiliary lobes, and an umbilical lobe. Intermediate saddles are rounded. The suture closely resembles that illustrated by figure 4 on Gemmellaro's plate 3 of 1887,

TEXT-FIG. 1—A suture of *Popanoceras multistriatum* Gemmellaro, based on the figured Tunisian specimen at a conch diameter of 15 mm., ×10.

being, however, less advanced as our specimen is smaller.

Remarks.—The adoral camera of this Tunisian individual is markedly short, indicating a fully mature stage of growth. Therefore, the conch when complete (with the body chamber) had a diameter of little more than 30 mm., about three-fifths that attained by Gemmellaro's types. Presumably this variation is within the limits of the species.

Occurrence.—Near the top of the Middle Permian section in the Djebel Tebaga area, Tunisia (stratigraphic unit 13 of Mathieu, 1949, p. 14).

Repository.—Termier Collection, Université d'Alger.

PERITROCHIA DARAE (Gemmellaro)

Stacheoceras darae GEMMELLARO, 1887, Gior. Sci. nat. ed econ., t. 19, p. 26,36–37, pl. 4, fig. 7–12; TOUMANSKY, 1931, [USSR] Geol. Surv., Palaeont. & Strat., p. 22,23,86,87,88; GRECO, 1935, Paleontogr. Italica, vol. 35, p. 164–165, pl. 14, fig. 10a–10c; MILLER & FURNISH, 1940, Geol. Soc. Amer., Spec. Pap. 26, p. 131.

A crushed fragmentary internal mold corresponds closely to this species, described long ago from the Sosio beds of Sicily. It has an estimated diameter of some 25 mm. and a corresponding height and width of conch of about 14 mm. and 11 mm.—the lateral measurement would be greater if the individual were not distorted. Small portions of test reveal the presence of fine sinuous transverse growth lines parallel to the constrictions, which form shallow lateral and moderately deep ventral sinuses.

This specimen represents only the adoral portion of the phragmocone, and its sutures are so closely crowded as to obscure details of the lobes. Each of the prongs of the bifid ventral lobe is unequally divided. The lateral lobes, five in number, tend to be subequal but decrease progressively in size; all are asymmetrically trifid with the ventral subdivision being the largest.

Remarks.—As has been suggested previously by several authors, this form is intermediate between typical *Stacheoceras* and *Peritrochia*. However, the general physiognomy of the conch and the number of major elements in its sutures are similar to those of the type species of *Peritrochia*, *P. erebus* Girty, from the Middle Permian in West Texas.

Occurrence.—Near the top of the Middle Permian section in the Djebel Tebaga area, Tunisia (stratigraphic unit 13 of Mathieu, 1949, p. 14). The specimen is preserved in dense yellow-brown limestone.

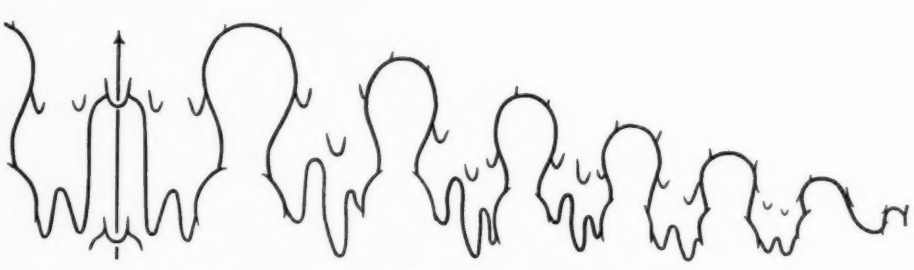
Repository.—Termier Collection, Université d'Alger.

STACHEOCERAS MEDITERRANEUM
Gemmellaro
Pl. 83, fig. 11,12

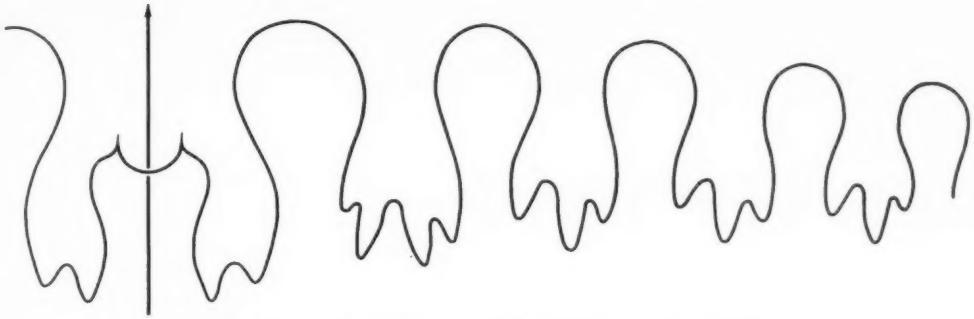
Stacheoceras mediterraneum GEMMELLARO, 1887, Gior. Sci. nat. ed econ., t. 19, p. 25,27–28, pl. 4, fig. 2–6, pl. 7, fig. 11–13; DE GREGORIO, 1930, Ann. Géol. et Paléont., Palermo, Livr. 52, p. 12; GRECO, 1935, Paleontogr. Italica, vol. 35, p. 113,162–163, pl. 14, fig. 7,8.

In November of 1950 Drs. Gilbert Castany and Gaston Delépine collected for three days at Djebel Tebaga. The former found an exceptionally fine representative of *Stacheoceras* and presented it to Monsignor Delépine, who later loaned it to us for study.

This specimen is a testiferous septate individual, well preserved in limonite. Its maximum overall dimension is about 37



TEXT-FIG. 2—A suture of *Peritrochia darae* (Gemmellaro), based on a Tunisian specimen at a conch diameter of ca. 20 mm., ×7.



TEXT-FIG. 3—A suture of *Stacheoceras mediterraneum* Gemmellaro, based on a figured Tunisian specimen at a conch diameter of 26 mm., ×10.

mm., and at its adoral end it attains a width and height of conch of 21 mm. and 19 mm., respectively.

The test is thin and on its surface bears fine lirae, which form lateral salients but are otherwise transverse. On the outer volution of the specimen there are four transverse constrictions parallel to the growth-lines; these are largely internal thickenings of the test for they are rather indistinct exteriorly. Within the small umbilicus there is a circular rim, a remnant of an additional full volution of the conch.

The external suture forms a bifid ventral lobe and on either side of it nine lateral lobes. Text-figure 3 portrays only the ventral lobe and the first four lateral lobes. The details of the remaining lateral lobes can not be observed, but it can be seen that the ninth is prominently bified. The umbilical lobe is complex. The internal suture consists of a dorsal lobe and on either side of it nine dorsolateral lobes, which are paired with the lateral lobes of the external suture.

Remarks.—This Tunisian individual corresponds closely with Sicilian specimens illustrated and described by Gemmellaro and with some from the same locality in the collections now available to us for study; all are conspecific. The form from the Middle Permian of Crimea which Toumansky (1931, p. 24–27,87, pl. 1, fig. 8–11) designated *Stacheoceras mediterraneum* var. *crimensis* is also similar, and presumably it is closely related, as are species from Timor and Coahuila. However, in almost all of these forms, the first lateral lobe of the sutures does not bear four digits, the significance of which is questionable.

Professor Henri Termier loaned us a poorly preserved specimen which is related to *S. mediterraneum*, but the proportions of it seem to agree with *S. globosum* Gemmellaro, also described originally from the Sosio beds of Sicily. Where the diameter of this specimen is some 20 mm., the width of its conch is about 16 mm. The umbilicus is small. Near the adoral end of this individual, each external suture forms eight lateral lobes, and the general course of the suture is arcuate. Traces of the internal sutures of an additional volution indicate that the phragmocone attained a size comparable to the specimen of *S. mediterraneum* that we are illustrating.

Occurrence.—Both of the specimens just described are labelled only as being from the Middle Permian of Djebel Tebaga, Tunisia.

Repositories.—Collection of Gaston Delépine, Université Libre de Lille (figured specimen); and Standard Oil Company collection, Université d'Alger.

PSEUDOGASTRIOCERAS-STRIGOGONIATIES spp.

Glyphioceras (*Anderssonoceras*) *angulatum* DOUVILLÉ, SOLIGNAC, & BERKALLOFF, 1933, Acad. Sci. Paris, C.R., t. 196, p. 23; SOLIGNAC & BERKALOFF, 1934, Tunisie, Serv. Carte Géol., Mém., n. sér., no. 1, p. 13,15,32,58–59.

Pseudogastrioceras cf. *P. roadense* CIRY & MATHIEU, 1947, Soc. Géol. France, C.R., p. 190; MATHIEU, 1949, Tunisie, Dir. Trav. Publics, Ann. Mines et Géol., sér. 1, no. 4, p. 13, 17.

Gastrioceratids (neoicoceratids) are the most abundant and characteristic ammonoids in Pennsylvanian and Permian strata. They are variable, and the bases for

distinction of genera and species are indefinite.

Solignac & Berkaloff (1934, p. 32) state that from varicolored sandstones in the midportion of the Tunisian Permian they had "un unique exemplaire de *Glyphioceras (Anderssonoceras) angulatum* Haniel absolument identique au type du Permien de Timor figuré par Haniel." This species is now the type of Spath's genus *Strigogoniatites*. However, Professor Henri Termier has indicated in a letter that the Tunisian specimen is poorly preserved.

Mathieu (1949, p. 13,17) indicates that shales and sandstones near the middle of the Tunisian Permian carry fusulinid limestone lenses which have yielded *Archeocidaris* fragments and a goniatite identified as *Pseudogastrioceras* cf. *P. roadense* (Böse). The last was compared with a small immature specimen from the Guadalupian of West Texas which was illustrated by us (Miller & Furnish, 1940, pl. 28, fig. 1,2).

We have not seen either of these Tunisian gastrioceratids that are recorded in the literature, nor have they been illustrated. Furthermore, the African collections available to us for study do not contain any representatives of this family.

MEDLICOTTIA TRAUTSCHOLDI Gemmellaro?

Medlicottia Orbignyana Trautscholdi DOUVILLÉ, SOLIGNAC, & BERKALLOFF, 1933, Acad. Sci. Paris, C.R., t. 196, p. 22; SOLIGNAC & BERKALOFF, 1934, Tunisie, Serv. Carte Géol., Mém., n. sér., no. 1, p. 9,31,43.

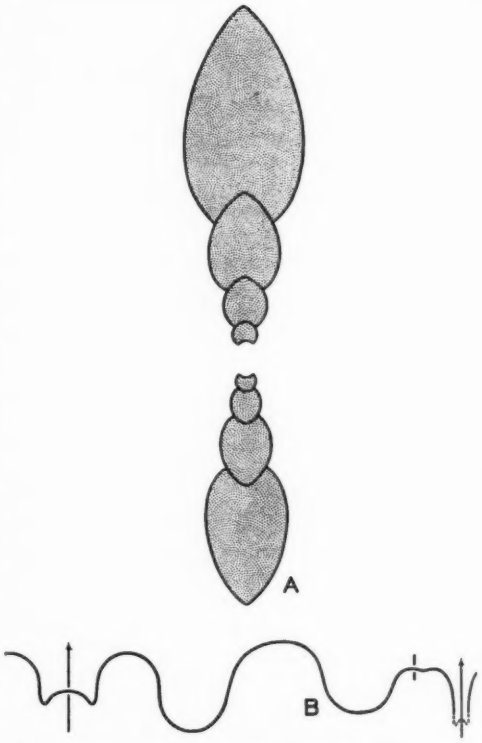
Medlicottia sp. CASTANY, 1953, Tunisie, Serv. Mines, Indust. et Energ., Carte Géol. Tunisie 1/500.000, notice explicative, p. 11.

Solignac & Berkaloff state that varicolored sandstones near the base of the Tunisian Permian have yielded some specimens of this medlicottiid. Professor Henri Termier has written us that he and Madame Termier were unable to locate any representatives of *Medlicottia* in the Permian collections at Tunis and at l'École des Mines, Paris. Monsignor Gaston Delépine has informed us that he saw a presumed *Medlicottia* at Tunis. We have not seen Solignac & Berkaloff's collections, but there are no medlicottiids in the materials now being studied.

Although quite a few medlicottias are known from the Middle Permian, they are not abundant. Either the shape of the conch or the suture is sufficient for generic recognition, but only reasonably complete well preserved individuals can be identified specifically. In any case, medlicottias are not good indices for detailed correlation within the Middle and Upper Permian.

CIBOLITES AFRICANUS M. & F., n. sp.
Pl. 83, fig. 3,4

The single specimen on which this species is based, the holotype, was found in 1952 by Dr. R. A. Bramkamp, who kindly donated it for study. It represents a small portion of the phragmocone at a diameter of about 11½ mm. The conch is discoidal, and the whorls are angular ventrally and shallowly impressed dorsally. On the surface of the test there are fine growth lines and



TEXT–FIG. 4—Cross section and suture of *Cibolites africanus* M. & F., n. sp., based on the holotype at a diameter of some 10 mm., ×7 and ×12½.

indistinct ribs, which form ventral and lateral salients—the ribs are clearly discernible on the inner volutions of the conch.

The sutures are characteristic of the genus and form two pairs of rounded lateral lobes. Also, there appears to be an incipient lobe at the umbilical seam. Most of our knowledge of the sutures in this genus and family comes from larger specimens, and the individual we are studying retains traces of an additional septate volution in which the sutures presumably were somewhat farther advanced. Therefore, the accompanying drawings probably do not display the fully mature characters.

Remarks.—In general, paraceltitids are good index fossils, but of course a single small specimen is not a very reliable basis for an age determination. Primitive forms, which occur in the early Middle Permian, are characterized by prominent sculpture, evolute whorls, and relatively simple sutures. In advanced forms, the sculpture is less pronounced, the whorls are somewhat more deeply impressed dorsally, and the sutures tend to form an additional lobe, which is located near the umbilical seam.

Gemmellaro distinguished four species of *Paraceltites* in the Sosio beds of Sicily. Of these, *P. plicatus* (Pl. 83, fig. 1) is a primitive form, *P. halli* is advanced, and *P. muensteri* and *P. hoeferi* (Pl. 83, fig. 2) are more or less intermediate—the last is the type species of the genus. *P. halli* is transitional between typical *Paraceltites* and *Cibolites*.

In the Permian of northern Mexico (Coahuila), several variants of paraceltitids occur in direct association. The characteristic form, *Cibolites*, represents an advanced stage of development within the family. The Tunisian specimen under consideration resembles representatives of *Cibolites* from northern Mexico and nearby West Texas. It can be regarded as suggesting a middle Guadalupian age. A few advanced forms known from the Sicilian Sosio beds (lower Guadalupian) are also closely similar.

The most prolific late Paleozoic ammonoid fauna that has been discovered is that of the Sosio beds. It carries two homeomorphs of the paraceltitids: *Clinolobus* (which is indeed rare) and *Epiglyphioceras*. Both are small discoidal evolute forms that are not known to occur outside Sicily. Sutures of the former, *Clinolobus*, suggest a relationship to the adrianitids, whereas those of the latter, *Epiglyphioceras*, are "gastrioceratid." Gemmellaro's excellent illustrations are lithographs that, with few exceptions, portray the specimens natural size, and for small individuals they are not as satisfactory as would appear at first sight. Furthermore, his monograph has become rare and is not readily available to most paleontologists. We have never seen a specimen of *Clinolobus*, but the collections of the U. S. National Museum contain seven specimens of *Epiglyphioceras*, the best of which is illustrated herewith (Pl. 83, fig. 5,6).

Occurrence.—Shale near top of the Baten Beni Zid sandstone, lower part of Tunisian Permian, in the Djebel Tebaga area. The specimen is a limonitic internal mold to which the calcareous shell adheres.

Repository.—State University of Iowa, 8298.

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EXPLANATION OF PLATE 83

All specimens illustrated on this plate are from the Sosio beds in the province of Palermo, Sicily (fig. 1, 2, 5, 6), or from strata of about the same age in the Djebel Tebaga area near Médenine, southern Tunisia (fig. *3,4,7–12*).

FIG. *1—Paraceltites plicatus* Gemmellaro [S.U.I., 8299], ×3.
2—Paraceltites hoeferi Gemmellaro [S.U.I., 2794], ×3.
3,4—Cibolites africanus Miller & Furnish, n. sp. [holotype, S.U.I., 8298], ×3.
5,6—Epiglyphioceras meneghinii Gemmellaro [U.S.N.M.], ×3.
7,8—Popanoceras multistriatum Gemmellaro [U. Alger], ×2½.
9,10—Agathiceras suessi Gemmellaro [S.U.I., 8297], ×2½.
11,12—Stacheoceras mediterraneum Gemmellaro [*U. Lille*], ×1½.

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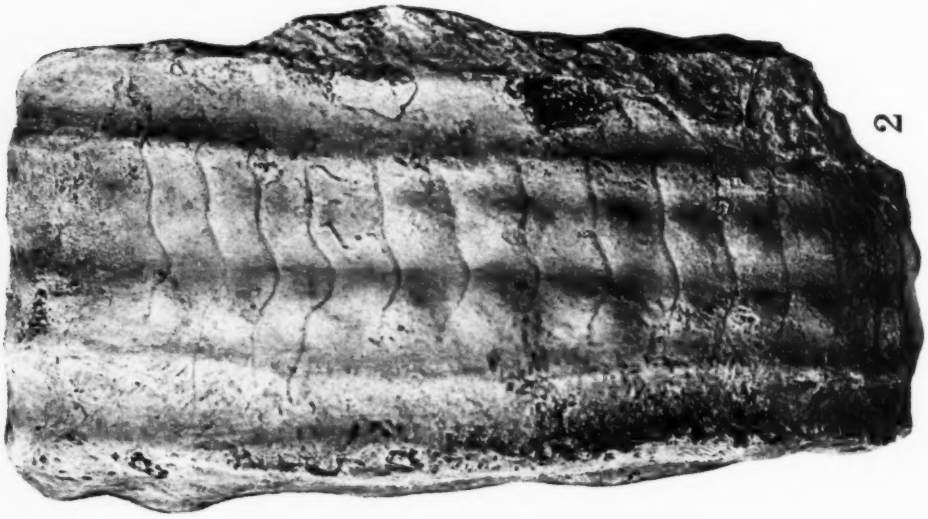

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JOURNAL OF PALEONTOLOGY, VOL. 31, NO. 4, P. 713–714, PL. 84, JULY 1957

A SECOND PERMIAN SPECIMEN OF THE NAUTILOID *AULAMETACOCERAS*

A. K. MILLER AND W. M. FURNISH
State University of Iowa, Iowa City

ABSTRACT—A representative of *Aulametacoceras mckeei* is illustrated and described. It came from the Kaibab limestone of Arizona.

ONE of the rarest of the Permo-Triassic nautiloid genera is *Aulametacoceras* Miller & Unklesbay, only a single Permian representative of which has been recorded in the literature. That specimen is the type of the genus, and it is from the Middle Permian Kaibab limestone of central Arizona. A form that is probably congeneric, *Nautilus rectangularus* Hauer, has been described from the Upper Triassic of the Carnic Alps, where it also is exceedingly rare (Mojsisovics, 1882, p. 271). No other members of the genus are known.

In view of these facts, the discovery of a second individual in the Kaibab seems to be worth recording, even though the specimen is from the same general locality as the type and appears to be conspecific with it. It was made available to us for study by Mr. L. F. Brady of the Museum of Northern Arizona, and we hereby acknowledge our indebtedness to him and to Dr. Frederick Leach, who retouched the accompanying photographs.

AULAMETACOCERAS MCKEEI
Miller & Unklesbay
Plate 84, fig. 1, 2

Aulametacoceras mckeei MILLER & UNKLESBAY, *1942*, Jour. Paleont., vol. 16, p. 726–728, text-fig. 1A, pl. 112, fig. 1,2; MILLER & YOUNGQUIST, 1949, Geol. Soc. Amer., Mem. 41, p. 9,42,93–94, text-fig. 6A, pl. 34, fig. 1,2; KUMMEL, *1953*, U. S. Geol. Surv., Prof. Pap. 250, p. 4,13,25,27,28,32, text-fig. 7C.

The specimen under consideration is a completely septate internal mold preserved in pink sandy dolomite. The maximum overall dimension of the preserved part of this individual measures about 170 mm., the corresponding diameter of the umbilicus is some 105 mm., and the greatest height and width of conch are about 60 mm. and 85 mm., respectively. The cross section is irregularly hexagonal as the broad venter and dorsum and the umbilical walls are nearly flat, and the lateral zones are only slightly concave. The width of the umbilical walls is about equal to that of the lateral zones of the conch, but is only about half as great as the ventral width.

The umbilical and the ventrolateral shoulders are subangular, and each bears a row of indistinct nodes. Along the middle of the venter there is a shallow rounded groove, which is bordered on either side by a row of rounded nodes. Outside these nodes is a small shallow rounded longitudinal groove, followed by a subangular ridge and then a more prominent rounded groove, which extends to a ventrolateral ridge.

The camerae are short, and there are some eleven of them in the adoral quarter-volution of the phragmocone. The ventral portion of the suture forms a broad shallow rounded lobe, the flanks of which are undulatory, reflecting the longitudinal grooves and ridges on the venter. The suture forms a rounded lobe on each of the lateral zones of the specimen, but on the umbilical walls it is nearly straight. No trace of the siphuncle is visible.

Remarks.—This specimen resembles the

EXPLANATION OF PLATE 84

FIG. *1,2*—*Aulametacoceras mckeei* Miller & Unklesbay. Two views of an internal mold of a phragmocone (Mus. N. Ariz., G2–4193) from the Kaibab limestone near Flagstaff, Arizona, ×4/5.

holotype of *A. mckeei* Miller & Unklesbay but is only about two-thirds as large. Its median ventral ridges are much more clearly nodose than those of the type, presumably because it represents an earlier growth stage of the conch. In general physiognomy it resembles *A. rectangulare* (Hauer) in which, however, the umbilicus is smaller, the cross section of the conch is more nearly rectangular, and the ventrolateral nodes are more prominent. Although these two forms differ materially in age, there seems to be no good reason to place them in different genera. The median ventral nodes on the specimen under consideration indicate a relationship to *Tainoceras*, from which *Aulametacoceras* almost certainly arose.

Occurrence.—Kaibab limestone near Flagstaff, Arizona. The holotype of this species came from about 10 miles southeast of Flagstaff, probably from the α member of the Kaibab.

Repository.—Museum of Northern Arizona, G2-4193.

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JOURNAL OF PALEONTOLOGY, VOL. 31, NO. 4, P. 715–736, PL. 85–88, 3 TEXT-FIG., JULY 1957

THE CONODONTS OF THE ORDOVICIAN MAQUOKETA FORMATION IN IOWA

ANNE TRELOAR GLENISTER
State University of Iowa, Iowa City

ABSTRACT—More than 800 identifiable conodonts were recovered from 124 samples taken from eight outcrops of the Maquoketa formation in northeastern Iowa. A total of 36 species, referable to 14 genera, are described and illustrated. Of these species, *Amorphognathus adunca*, *A. tridigitatus*, *Belodus dispansus*, *Ozarkodina inclinata*, and *Paltodus feulneri* are new. *Ambalodus* and *Amorphognathus* were recovered from the basal phosphatic member. *Drepandous homocurvatus* and *Phragmodus undatus* are conspicuous faunal elements from near the base of the formation to the top of the medial Ft. Atkinson member. *Belodus* and a distinctive representative of *Oistodus*, *O. abundans*, are present in the lower part, Elgin member, and range to the top of the Ft. Atkinson member. Species of *Dichognathus*, *Phragmodus*, and *Paltodus* were recovered from all five members. A small number of larger forms was recorded from the upper limestone of the Brainard member; *Paltodus feulneri* and *P. intermedius* are the most distinctive species of this limestone.

INTRODUCTION

THE Maquoketa formation is generally considered to be of Upper Ordovician age (Twenhofel et al., 1954). The present investigation is a study of the conodont faunas from the outcrops of this formation in the northeastern portion of Iowa.

Random samples were first taken at Cascade Gulch, Fayette County. Another general sample was collected from the Brainard member in the same county at Patterson's Spring. Five other complete or partially exposed sections of the Maquoketa formation were then sampled in detail. Four of these localities were in Clayton County, and one was in Fayette County. Within the Elgin and Ft. Atkinson members, two-foot samples were taken. Additional samples were collected at each significant change in lithology. Two-foot, gallon, channel samples were taken in the Clermont member and parts of the Brainard member. The shales of the Brainard member were commonly slumped, thus rendering accurate sampling difficult. In the laboratory, the shales were heat-treated with kerosene and water. The limestones and dolomites were reduced in acetic acid. All residues were washed on a 115-mesh screen, and then either hand-picked or gravity separated in tetrabromethane. Over 800 identifiable specimens, referable to 36 species and 14 genera, resulted from the treatment.

The author is indebted to Dr. W. M. Furnish for general supervision over all the work. Dr. A. K. Miller gave invaluable advice, especially during the early stages of the project. Mr. and Mrs. A. J. Feulner helped immeasurably in the field work. Dr. C. R. Stauffer's Maquoketa formation collections from Minnesota were made available through the courtesy of Dr. Frederick M. Swain. Dr. Brian F. Glenister assisted greatly in the preparation of the final manuscript. The work was largely financed by the Iowa Geological Survey. All type and figured specimens are deposited at the State University of Iowa.

THE MAQUOKETA FORMATION OF IOWA

In general, all the Paleozoic rocks of northeastern Iowa dip gently to the southwest. However, this dip is not a significant factor in the measurement of individual sections, whereas local slumping poses sampling problems. The Maquoketa formation crops out in a belt along the eastern margin of Iowa (Ladd, 1929, p. 439, pl. 16). Four members, mostly carbonate, are discernible in the north, and the formation changes progressively southward, within Clayton and Dubuque counties, into a shale facies. However, a communication from the Iowa Geological Survey relates the finding of calcareous beds in the southern exposures, which seem to correspond strati-

graphically to the carbonate members in the north. Earlier workers have referred to the outcrops as the "Maquoketa shales," but in this paper the Maquoketa of Iowa will be termed a "formation."

The lowermost member consists of argillaceous limestones and interbedded shales. It is named from an exposure near the town of Elgin, Iowa, where only the lower portion of the member is now visible. The overlying greenish-blue shale, the Clermont member, was named from once-good exposures in a clay pit near Clermont, Iowa. This area is now under cultivation. The succeeding Ft. Atkinson member consists of chert and dolomite. The type locality is still exposed in a quarry near the old fort at Ft. Atkinson, Iowa. Above the dolomite is a large thickness of plastic shale, and bedded limestone which was named after the community of Brainard, Iowa. It is well exposed in a deep gulley at Patterson's Spring, about a mile north of Brainard.

The phosphatic "Depauperate zone" at the base of the Elgin member was first described by Ladd (1929, p. 371–384). The term "depauperate" has since been discussed by Tasch (1953, p. 402,403). Although Tasch (1953, p. 419,420) states that only further study will reveal the true nature of the fauna, he advances the ideas that it may be an example of pebble-necrocenosis. Irrespective of the justification for a zonal terminology for these beds, they represent a lithologic unit. For this reason, the beds of the "Depauperate zone" will be considered in the present paper as a separate member of the Maquoketa formation. The beds in question consist of slightly calcareous, highly ferruginous clay, and they contain numerous phosphatic pebbles and pyrite crystals. The unit has never received a formal stratigraphic name, and it will be referred to in this paper as the "phosphatic member."

Two samples were taken in the upper Brainard member (unit 5 of Ladd's section, 1929, p. 339, characterized by the presence of *Cornulites sterlingensis*). This fossiliferous limestone, and overlying clay, in the uppermost Brainard member, has been given the name Cornulites zone by Ladd, but will be termed the limestone of the Brainard member in this study.

OCCURRENCE OF CONODONTS IN THE MAQUOKETA FORMATION

The most extensive conodont collections were recovered from the Clermont member. Although it is fossiliferous throughout, larger numbers of specimens were found in the lower portion of this shale. The limestone of the Elgin member, sampled at Locality 7, produced the best-preserved forms, as even the fragile oral bars of *Phragmodus undatus* were recovered. Numerically smaller, and poorly preserved faunas were recovered from the dolomitic facies of the Elgin member. The Ft. Atkinson dolomite was found to be very slow to digest in acid and revealed only a very limited conodont fauna. Few samples of the Brainard member were collected, and slumping made accurate sampling difficult. In any case, when reduced, these shales proved to be virtually unfossiliferous. From the limestone of the Brainard member, a small number of large distinct forms was recovered. Tables 1 and 2 summarize the stratigraphic distribution of the conodonts within the Maquoketa formation in Iowa. Sections from which conodonts were collected may be located by reference to Text-figure 1.

IOWA MAQUOKETA CONODONT LOCALITIES

Locality 1.—All 5 members of the Maquoketa formation are exposed in the steam cut which crosses a gravel road about 7½ miles northeast of Wood (NE¼ SW¼ sec. 14, T. 91 N., R. 4 W., Elk Township, Clayton County). Present are: 4 inches of the basal phosphatic member, 38 feet of the highly dolomitic Elgin limestone and the underlying chocolate shale, 14 feet of Clermont shale, 18.5 feet of Ft. Atkinson dolomite, and 100+ feet of Brainard plastic shale. Forty-four samples were taken from the phosphatic member upwards through the lower Brainard member. The most numerous conodonts were found in the Clermont member.

Locality 2.—The phosphatic and lower Elgin members were sampled in a quarry on the north bank of the Volga River, west of Littleport (SW¼ NE¼ sec. 25, T. 92 N., R. 5 W., Cox Creek Township, Clayton County). One foot of the phosphatic member was present, and approximately 4 feet of

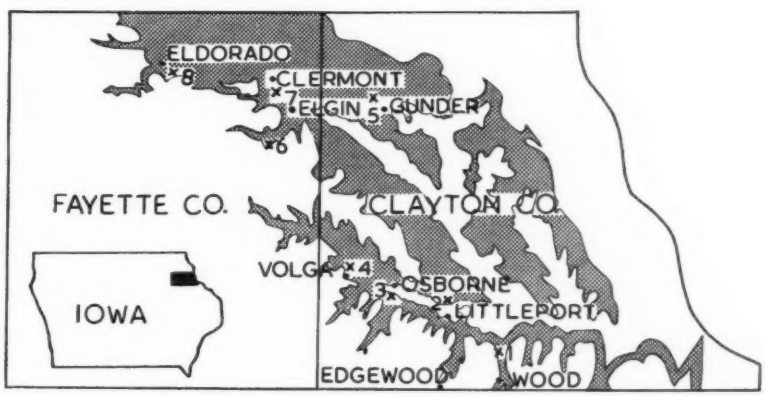
TABLE 1—DISTRIBUTION OF MAQUOKETA CONODONTS, PART 1

CONODONT GENERA AND SPECIES (simple cone forms)	PHOSPHATIC	ELGIN	CLERMONT	FT. ATKINSON	BRAINARD SH.	BRAINARD LS.
DREPANODUS Pander						
D. cf. *D. arcuatus* Pander	– – – –					
D. concavus (B.&M.)	– – – –					
D. homocurvatus Lindström	———	– – – –	———	– – – –		
D. cf. *D. subarcuatus* Furnish	– – – –	– –				
OISTODUS Pander						
O. abundans B.&M.		———	———	– – – –		
O. excelsus Stauffer	– – – –					
O. inclinatus B.&M.	– – – –	– – – –	– – – –			
O. parallelus Pander	– – – –		– – – –	– – – –	– – – –	
O.? suberectus B.&M.	– – – –	– – – –	– – – –			
O. venustus Stauffer	– – – –					
PALTODUS Pander						
P.? acostatus B.&B.	– – – –	– – – –	———	———		– – – –
P. fuelneri Glenister, n. sp.						———
P. gracilis B.&M.	———	– – – –	———	———		———
P. intermedius, B., M.&B.						———
P. panderi Stauffer	– – – –	– – – –	———	– – – –	– – – –	– – – –
P. striatus Stauffer		– – – –	– – – –	– – – –		
P.? unicostatus B.&M.	– – – –	– – – –	– – – –	———	– – – –	– – – –

chocolate shale was recorded above. Eight feet of argillaceous, dolomitic limestone, and intervening shale layers, were present from the top of the chocolate shale to a soil cover. Very poorly preserved specimens were recovered from the phosphatic member. The chocolate shale was almost barren, and only a limited number of conodonts were extracted from the overlying limestone.

Locality 3.—The phosphatic and lower Elgin members are exposed in a quarry on the north bank of the Volga River, approximately a mile above Osborne (NC S½ sec. 9, T. 92 N., R. 5 W., Cox Creek Township, Clayton County). One foot of the phosphatic member and .5 foot of the overlying chocolate shale were recorded. Over 24 feet of the Elgin argillaceous dolomitic limestone is exposed. Fourteen samples were collected, and a small conodont fauna was recovered.

Locality 4.—A complete section of the Elgin member is exposed along the north-



TEXT-FIG. 1—Index map of Iowa showing locations of collections.

TABLE 2—DISTRIBUTION OF MAQUOKETA CONODONTS, PART 2

CONODONT GENERA AND SPECIES (compound forms)	PHOSPHATIC	ELGIN	CLERMONT	FT. ATKINSON	BRAINARD SH.	BRAINARD LS.
AMBALODUS Branson & Mehl						
A. triangularis B.&M.	———					
AMORPHOGNATHUS Branson & Mehl						
A. adunca Glenister, n. sp.	———					
A. complicata Rhodes	———					
A. ramosa (Stauffer)	———					
A. tridigitata Glenister, n. sp.	- - - -					
BELODUS Pander						
B. dispansus Glenister, n. sp.		- - - -	- - -			
B. ornatus B.&M.		- - - -	———	- - - -		
CORDYLODUS Pander						
C.? delicatus B.&M.	- - - -	- - - -	- - -			
C. primus B.&M.	- - - -					
CYRTONIODUS Stauffer						
C. complicatus Stauffer	- - - -					
DICHOGNATHUS Branson & Mehl						
D. brevis B.&M.	- - - -	———	———	- - - -	- - - -	
D. extensa B.&M.		———	———	———	- - - -	
D. typica B.&M.		———	———	- - - -	- - - -	
LIGONODINA Ulrich & Bassler						
L. sp.	- - - -					
OZARKODINA Branson & Mehl						
O. delecta Stauffer	- - - -					
O. inclinata Glenister, n. sp.	———					
PHRAGMODUS Branson & Mehl						
P. undatus B.&M.	- - - -	———	———	———	- - - -	- - - -
ROUNDYA Hass						
R. inclinata (Rhodes)	———					
TRICHONODELLA Branson & Mehl						
T. flexa Rhodes	- - - -					

east bank of the Volga River at Volga (S½ sec. 3, T. 92 N., R. 6 W., Sperry Township, Clayton County). Here the member consists of argillaceous dolomite and interbedded shales. It is underlain by the phosphatic member, which here attains a thickness of only 4 inches. A sparse and poorly preserved fauna was recovered from 30 samples; the bulk of the specimens were from the phosphatic member.

Locality 5.—A small quarry on the northern boundary of section 4, northwest of Gunder (sec. 4, T. 94 N., R. 6 W., Marion Township, Clayton County) exposes a complete section of the Clermont member. It consists of 14 feet of greenish-blue plastic shale, and it grades downward into the Elgin member. A well preserved fauna was recovered from the 8 samples taken. Three samples from the Ft. Atkinson dolomite ledge above the shale yielded only a few poorly preserved specimens.

Locality 6.—The limestones and upper shales of the Brainard member are still well exposed in the Patterson's Spring locality described by Ladd (1929, p. 338,339). The

section is located one mile north of the village of Brainard (W½ NW¼ sec. 20, T. 94 N., R. 7 W., Pleasant Valley Township, Fayette County). Unit No. 5 of Ladd (1929, p. 339) was sampled, and a number of large conodonts as recovered. The shale samples contained few.

Locality 7.—The *Isotelus maximus* beds (Ladd, 1929, p. 333,334) of the Elgin member are well exposed in the stream cut which crosses country road "Y" in the outskirts of Clermont (SW¼ NW¼ sec. 35, T. 95 N., R. 7 W., Clermont Township, Fayette County). An extremely well preserved fauna was recovered from the several 4 to 8 inch argillaceous limestone layers. These trilobite-rich layers break with the smooth conchoidal fracture that is characteristic of the member in most areas. The limestone alternates with shale layers, but the latter contain only a sparse conodont fauna.

Locality 8.—Random samples were taken at the beginning of the project from the lower Elgin limestone through the Brainard shale, at Cascade Gulch (SW¼ sec. 17, T. 95 N., R. 8 W., Dover Township, Fayette County). Ten samples were collected in the lower, middle and upper parts of the members, and a channel sample was taken through the Brainard shales. A well preserved fauna was recovered from the argillaceous limestones and interbedded shales of the Elgin member. The characteristic greenish-blue plastic shales of the Clermont member yielded the most specimens. Only a few well preserved conodonts were recovered from the Ft. Atkinson dolomite, and the soft greenish shales of the Brainard member were almost barren.

SIGNIFICANCE OF THE IOWA MAQUOKETA CONODONTS

Three distinct conodont faunas were recovered from the Maquoketa formation in Iowa. *Ambalodus* and *Amorphognathus* are the most characteristic faunal elements of the phosphatic member, and they are not present above it. The lowermost shale of the Elgin member, immediately overlying the phosphatic member, yielded only a few specimens of *Phragmodus*. Although genera other than the two mentioned above were represented in the phosphatic member (Table 1, 2), only a limited number of species of each genus was recovered. A larger number of species appeared in the more indurated layers of the Elgin member, and they were present in the overlying members. *Belodus* was recorded in the limestones of the Elgin member, and it was present throughout in samples to the top of the Ft. Atkinson member. The shales of the Brainard member were found to be almost barren of conodonts; the few representatives recovered indicated a continuation of the same faunal elements that were observed in the Elgin limestones. The third fauna was recorded from the limestones of the upper Brainard member. These forms are larger in size than those of the members below. In addition, two Brainard species of *Paltodus*, one of which is new, were not recovered below the upper portion of the member.

Rhodes (1953, p. 271–273) correlated the Maquoketa-Thebes conodont faunas of Missouri and those of the Maravillas formation of Texas with the Gelli-grin Limestone of North Wales, and he considered them to be of Upper Caradocian age. The Caradocian has been generally regarded as older than the Richmond group. Such a conclusion has been based partly upon the presence of *Ambalodus* and *Amorphognathus* in all the formations listed (Table 3); genera which are absent from the Richmondian (Rhodes, 1955, p. 119–122). Both *Belodus* and *Phragmodus* are represented in older formations, as well as the Maquoketa formation. *Belodus* is not positively identified above this formation, and only "degenerate, atypical forms" of *Phragmodus* (Branson, et al., 1951, p. 4) have been recorded in supposed Maquoketa equivalents, including basal Richmond (Arnheim formation). The most distinctive element of the Richmondian fauna (Branson et al., 1951, p. 4,5) is the large variety of *Paltodus*. The genera *Trichonodella*, *Ligonodina*, *Cordylodus*, and *Prioniodus* are not of much correlative value in this case, although individual species may be significant (Rhodes, 1955, p. 122).

Collectively, the three faunas of the Maquoketa formation of Iowa are transitional in aspect between those of the pre-Richmondian strata and those of the Richmondian. The presence of *Ambalodus* and *Amorphognathus* in the phosphatic member gives this earlier fauna a close resemblance to all the formations listed on Table 3 except the Richmond group. However, this overall

TABLE 3—KNOWN DISTRIBUTION OF SOME MAQUOKETA CONODONT GENERA IN COMPARABLE ORDOVICIAN STRATA

STRATIGRAPHIC UNITS \ GENERA	AMBALODUS	AMORPHOGNATHUS	BELODUS	CORDYLODUS	DICHOGNATHUS	DREPANODUS	LIGONODINA	OISTODUS	OZARKODINA	PALTODUS	PHRAGMODUS	TRICHONODELLA s. l.
MARAVILLAS FM., TEXAS	×	×	×	×		×		×	×	×	×	×
THEBES SANDSTONE (MAQUOKETA), MISSOURI	×	×	×	×					×		×	×
MAQUOKETA SHALE, KANSAS	×	×	×	?	?	×		×	×	×	×	×
GELLI-GRIN LIMESTONE, N. WALES	×	×		×		×	×	×		×	×	×
PEN-Y-GARNEDD LIMESTONE, N. WALES	×	×				×	×	×		×	×	×
KEISLEY LIMESTONE, WESTMORLAND	×	×		×		×	×	?		?	×	×
RICHMOND GROUP, KENTUCKY						×	×	?		×		×
MAQUOKETA FM. IOWA — PHOSPHATIC MEMBER	×	×		×	×	×	×	×	×	×	×	×
MAQUOKETA FM. IOWA — ELGIN, CLERMONT, FT. ATKINSON MEMBERS & SHALE OF BRAINARD MEMBER			×	×	×	×		×		×	×	
MAQUOKETA FM. IOWA — LIMESTONE OF BRAINARD MEMBER										×	×	

similarity decreases in the later fauna of the intermediate members. Although a few species of *Paltodus* are recorded in the phosphatic member, a larger number of species of this genus is present in the overlying members (Table 1). *Belodus* was observed in the Elgin member; it was also recovered from the Maquoketa formation of Missouri and Kansas, as well as from the Maravillas formation of Texas. Only one species of *Phragmodus* is present throughout the Maquoketa formation of Iowa, and it is represented by large numbers of individual specimens. *Paltodus* is, in addition, the dominant element in the limestone fauna of the upper Brainard member. *Paltodus intermedius* was recovered as part of this fauna, and this species is comparable to the specimens figured by Branson et al. (1951, Pl. 1, fig. 9–15) from the Richmond group.

A fairly close similarity exists between the faunas of the Maquoketa formation and those of the Richmond group, although Branson et al. (1951, p. 3,4) designate the Maquoketa fauna as being older. If the presence of *Ambalodus* and *Amorphognathus* can be used to designate formations older than the Richmond (Rhodes, 1955, p. 121), the basal phosphatic member would likely be uppermost Maysvillian; the overlying members, therefore, Richmondian in age. This basis of distinction, however, does not

take into account the lithologic nature of the phosphatic member; ecologic factors may have been of importance.

In conclusion, the conodont fauna of the Maquoketa formation of Iowa contains a larger number of genera and species than has been recorded for the same formation in other states. The distinctive fauna of the phosphatic member indicates a pre-Richmondian age. The younger members of the Maquoketa formation contain a conodont fauna which, in aggregate, seems to be Richmondian or possibly slightly older.

THE MINNESOTA CONODONT COLLECTIONS

Dr. C. R. Stauffer's Maquoketa formation collections from Minnesota were made available for study. The collections are from a mile east of Spring Valley, and from the vicinity of Wykoff, both in Fillmore County.

Listed below are the conodont species identified from these collections.

SPRING VALLEY

Ambalodus triangularis
Amorphognathus sp. (fragments)
Belodus ornatus
Cordylodus? delicatus
Cyrtoniodus complicatus
Drepanodus concavus
Drepanodus homocurvatus
Oistodus excelsus
Oistodus parallelus
Ozarkodina delecta
Ozarkodina inclinata
Paltodus? acostatus
Paltodus gracilis
Paltodus panderi
Paltodus? unicostatus
Roundya inclinata
Trichonodella flexa

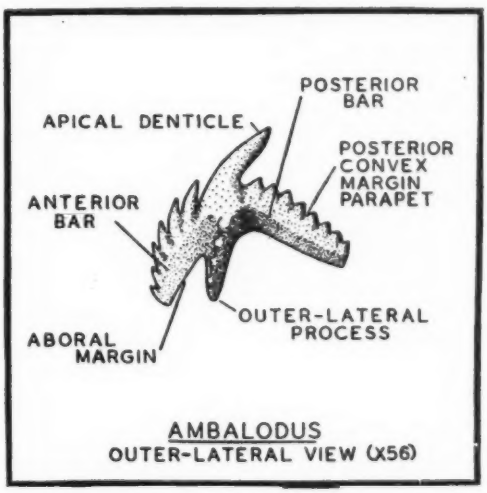
WYKOFF

Cordylodus? delicatus
Cyrtoniodus complicatus
Drepanodus concavus
Drepanodus homocurvatus
Oistodus? abundans
Oistodus parallelus
Ozarkodina delecta
Ozarkodina inclinata
Paltodus gracilis
Paltodus panderi
Paltodus? unicostatus

SYSTEMATIC PALEONTOLOGY

Order CONODONTOPHORIDA
Eichenberg, 1930
Suborder NEURODONTIFORMES
Branson & Mehl, 1944
Family TRUCHEROGNATHIDAE
Branson & Mehl, 1944
Genus AMBALODUS Branson & Mehl, 1933
Type species: *A. triangularis*
Branson & Mehl, 1933

Ambalodus was proposed to include triangular or crescent-shaped platform-like forms with an excavated aboral surface and a slightly concave, smooth oral surface. A parapet-like row of fused denticles, with a large denticle at the apex, is developed along the convex margin of the oral surface. An outer-lateral process is formed on the convex side of the apical denticle (Text-fig. 2).



TEXT-FIG. 2

The development of denticulation on this process varies widely.

Remarks.—Only one species, *A. triangularis* Branson & Mehl (1933, p. 128) had been described until Rhodes (1953, p. 278–281) added four new representatives, *A. elegans*, *A. pulcher*, *A. robustus*, and *A.* sp., together with a new variety, *A. triangularis indentatus*.

AMBALODUS TRIANGULARIS
Branson & Mehl
Pl. 88, fig. 20,21

Ambalodus triangularis BRANSON & MEHL, 1933, Mo. Univ. Studies, vol. 8, no. 2, p. 127,128, pl. 10, fig. 35–37; FAY, 1952, Univ. Kansas Paleont. Contrib., Vertebrata, art. 3, p. 62; RHODES, 1953, Phil. Trans. Roy. Soc. London, ser. B., no. 647, vol. 237, p. 280.

The dental units of this species consist of a curved, longer anterior and shorter posterior bar which meet to form a crescent-shaped, aborally excavated, main segment. An outer-lateral bar, originating on the convex margin of the crescent, gives an overall triangular appearance to the specimen. On the convex margin of the anterior bar, a parapet is formed by 8 to 10 low, rounded, fused denticles. These increase in size progressively toward the prominent apical denticle; the 4 adjacent to the apical denticle, in some forms, are markedly larger than the others. The denticulation of the posterior bar is not as well developed. The apical denticle is stout. It is directed posteriorly, and it develops a broadly convex outer side and a flat to gently convex inner side. Two carinae rise from the denticulate parapet, along the antero-posterior sides of the apical denticle, and they decrease in size to the tip. The concave inner margin forms an orally directed flange which is distinct on the anterior bar, merges into a moderate ridge opposite the apical denticle, and continues as such onto the posterior bar. The outer-lateral process is short, and it forms a medial ridge which, in some cases develops 1 or 2 low fused denticles.

Remarks.—The Maquoketa specimens conform closely to those originally described by Branson & Mehl. They are redescribed above in terms of Rhodes's (1953, p. 278, fig. 1) orientation diagram. The outer-lateral processes of the Iowa specimens are fragile. They are usually broken and are not well enough preserved to permit complete description of the species.

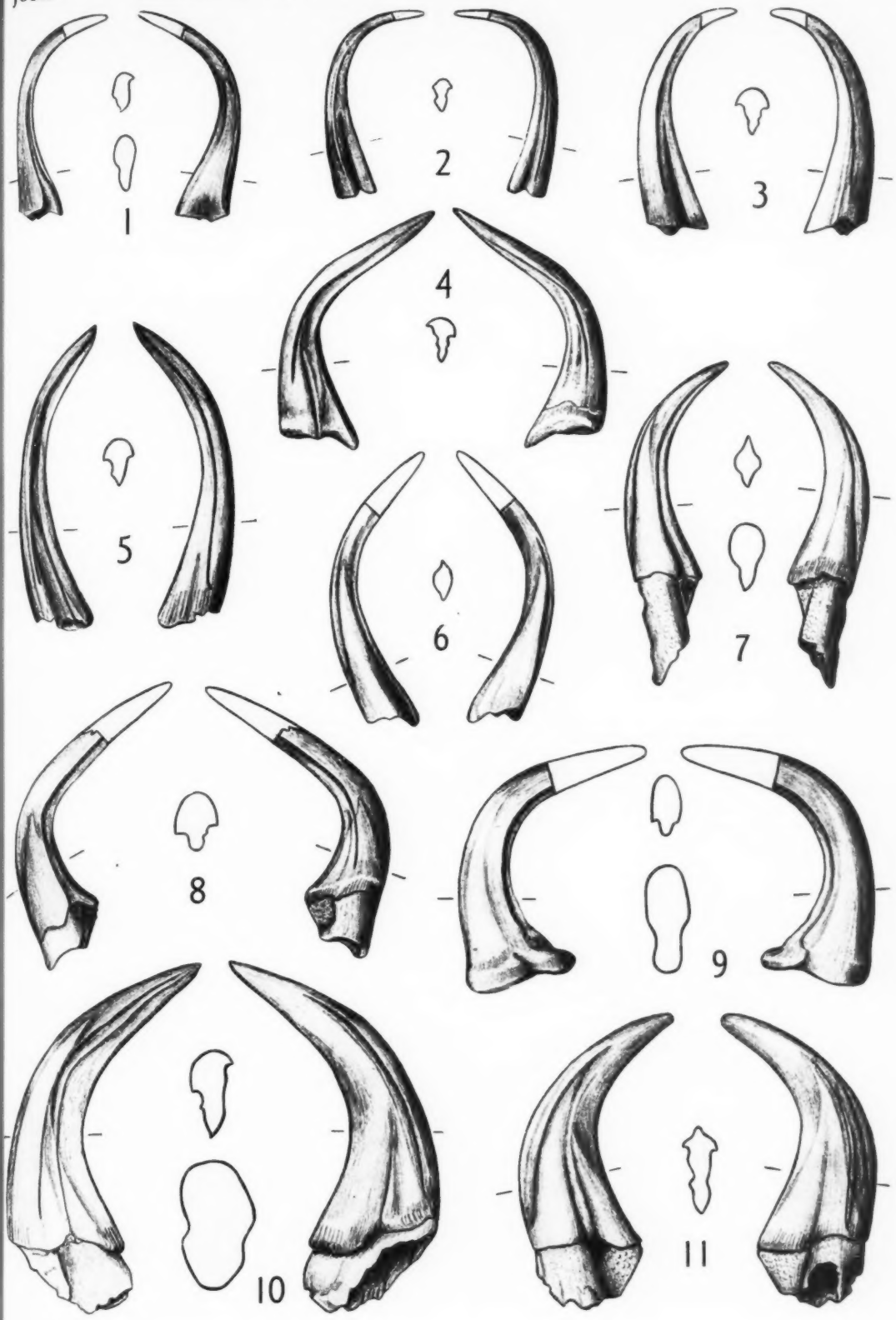
Occurrence.—In Iowa, the species was recovered only from the phosphatic member of the Maquoketa formation. A specimen was also identified from Stauffer's collection at Spring Valley, Minnesota.

Genus AMORPHOGNATHUS Branson & Mehl, 1933
Type species: *A. ordovicica* Branson & Mehl, 1933

Amorphognathus was proposed to include the irregularly branched, asymmetrical, platform-like forms which consist of an oral and an aboral plate. The oral surface is flat with raised, sometimes nodose margins, and a conspicuous longitudinal median crest which may be crenulate, nodose, or constructed of low, fused denticles. The aboral surface of the oral plate may develop a groove which corresponds to the oral crest, and also a distinct marginal groove and flange. The flange margin forms the junction between the oral and aboral plates. The aboral plate is flat or convex orally, and a median longitudinal crest is developed in some species. This plate is commonly broken or completely destroyed. The bars vary in number and length, and in their develop-

EXPLANATION OF PLATE 85

FIG. *1*—*Paltodus? unicostatus* Branson & Mehl. Clermont member, Locality 5, hypotype (4897), ×55.
2–5—*Paltodus gracilis* Branson & Mehl, ×55. *2*, Lower Ft. Atkinson member, Locality 5, hypotype (4888); *3*, Lowermost Ft. Atkinson member, Locality 5, hypotype (4889); *4*, Elgin member, Locality 2, hypotype (4890); *5*, Limestone of Brainard member, Locality 6, hypotype (4891).
6—*Paltodus striatus* Stauffer. Lower Ft. Atkinson member, Locality 5, hypotype (4896), ×55.
7—*Paltodus? acostatus* Branson & Branson. Clermont member, Locality 8, hypotype (4884), ×55.
8,9—*Paltodus panderi* Stauffer, ×55. *8*, Limestone of the Brainard member, Locality 6, hypotype (4894); *9*, Spring Valley, Minnesota, hypotype (4895).
10—*Paltodus intermedius* Branson, Mehl & Branson. Limestone of the Brainard member, Locality 6, hypotype (4892), ×40.
11—*Paltodus feulneri* Glenister, n. sp. Limestone of the Brainard member, Locality 6, holotype (4886), ×40.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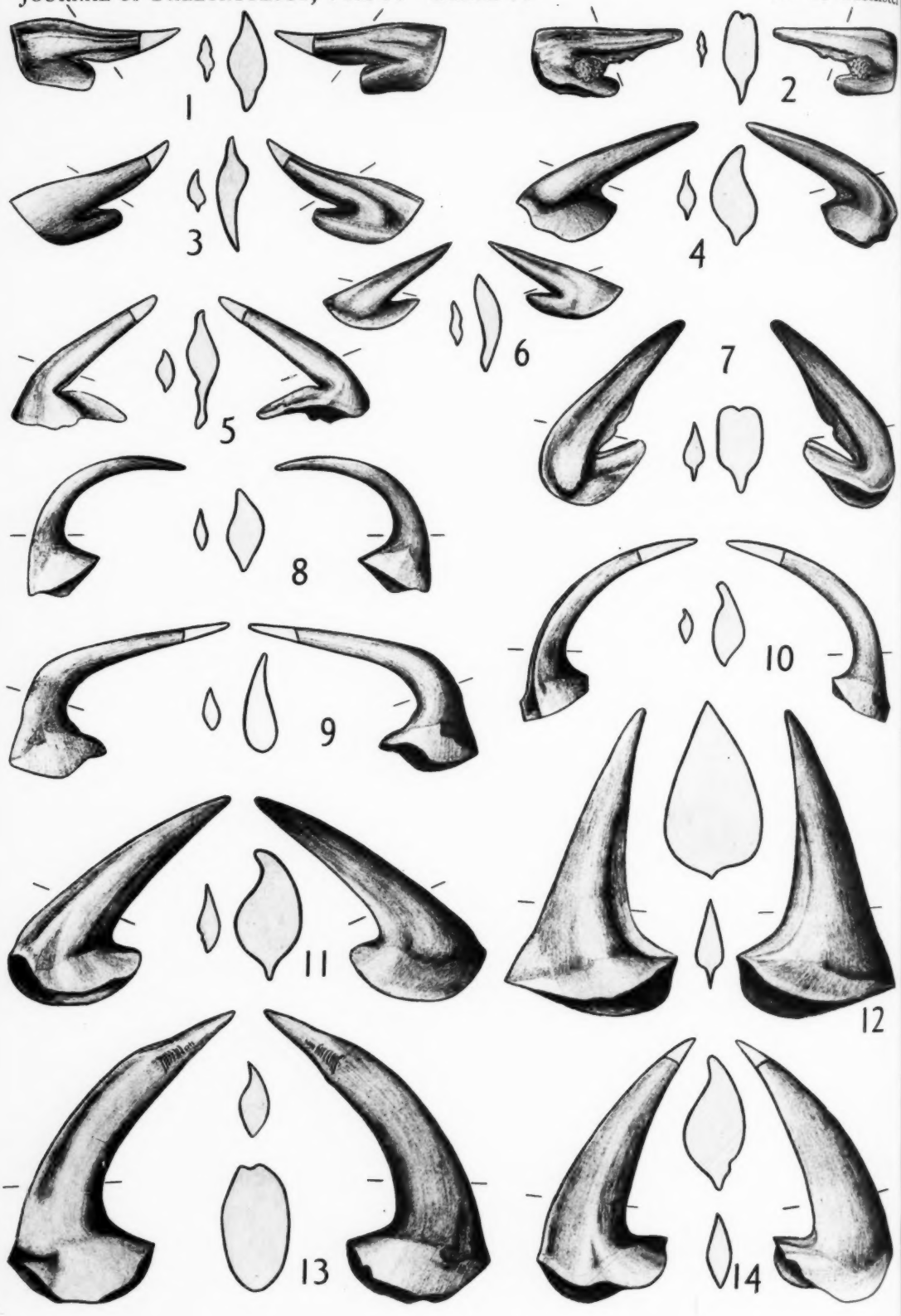
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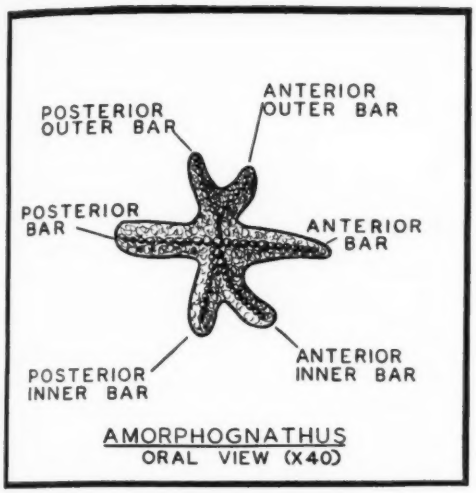


TEXT-FIG. 3

ment from a common junction area (Text-fig. 3). They are bulbous to slender in outline.

Polyplacognathus Stauffer is considered to be a junior synonym of *Amorphognathus* Branson & Mehl (Fay, 1952, p. 63,205).

Remarks.—In Iowa, the Maquoketa specimens are generally poorly preserved; they occur only in the basal phosphatic member. Secondary phosphatic deposition obscures the oral and aboral surface features. In some cases, only the gross outline of the specimen is discernible. Fragments of *Amorphognathus* were also found in Stauffer's collection made at Spring Valley, Minnesota.

AMORPHOGNATHUS ADUNCA
Glenister, n. sp.
Pl. 88, fig. 23,24

The dental units of this species consist of two unbranched bars, which meet to form an angle of approximately 160°. The posterior bar is straight, whereas the posterior one-third of the anterior bar bends sharply inward. The apex of the bend approximates the other bar at one-fourth of the length from its outermost tip. The posterior bar is frequently broken, so as to appear to connect directly to the anterior bar at the apex of the bend, and to lack any outer extension. Both bars have smooth, sharp, slightly elevated oral margins and a distinct, sharp, median longitudinal crest. This crest may be more or less nodose, or it may consist of a series of low fused denticles. The aboral plate is either flat or slightly convex orally.

Occurrence.—The species was recovered from only the lowermost phosphatic member of the Maquoketa formation in Iowa.

Repository.—Figured syntypes, S.U.I., 4854,4855; and unfigured syntypes, 4856.

AMORPHOGNATHUS COMPLICATA
Rhodes
Pl. 88, fig. 26

Amorphognathus complicatus RHODES, 1953, Phil. Trans. Roy. Soc. London, ser. B., no. 647, vol. 237, p. 282, pl. 20, fig. 42,45,46.

Remarks.—Rhodes's type material is closely similar to the Iowa specimens.

Occurrence.—In Iowa, the species was re-

EXPLANATION OF PLATE 86

FIG. *1–3—Oistodus parallelus* Pander, ×55. *1*, Upper Clermont member, Locality 1, hypotype (4878); *2*, Uppermost Clermont member, Locality 5, hypotype (4879); *3*, Upper Ft. Atkinson member, Locality 1, hypotype (4880).

4,7—Oistodus excelsus Stauffer, ×55. *4*, Spring Valley, Minnesota, hypotype (4875); *7*, phosphatic member, Locality 4, hypotype (4876).

5—Oistodus abundans Branson & Mehl. Clermont member, Locality 8, hypotype (4873), ×55.

6—Oistodus venustus Stauffer. Phosphatic member, Locality 4, hypotype (4883), ×55.

8—Drepanodus cf. *D. arcuatus* Pander. Phosphatic member, Locality 4, hypotype (4862), ×55.

9—Drepanodus cf. *D. subarcuatus* Furnish. Phosphatic member, Locality 4, hypotype (4872), ×40.

10—Drepanodus concavus (Branson & Mehl). Wykoff, Minnesota, hypotype (4863), ×40.

11—Oistodus inclinatus Branson & Mehl. Uppermost Clermont member, Locality 5, hypotype (4877), ×55.

12,14—Oistodus? suberectus Branson & Mehl. *12*, Phosphatic member, Locality 4, hypotype (4881), ×40; *14*, Clermont member, Locality 5, hypotype (4882), ×55.

13—Drepanodus homocurvatus Lindström. Clermont member, Locality 5, hypotype (4864), ×40.

covered from only the lowermost phosphatic member of the Maquoketa formation.

Repository.—Figured hypotype, S.U.I., 4857; and unfigured hypotypes, 4858.

AMORPHOGNATHUS RAMOSA (Stauffer)
Pl. 88, fig. 27

Polyplacognathus ramosus STAUFFER, 1935, Jour. Paleont., vol. 9, p. 615, pl. 75, fig. 23, 28–31, 37; FAY, 1952, Univ. Kansas Paleont. Contrib., Vertebrata, art. 3, p. 163.

Amorphognathus ramosa BRANSON & MEHL, 1944, *in* Shrimer & Shrock, Index Fossils of North America, p. 237, pl. 93, fig. 5,6; FAY, 1952, Univ. Kansas Paleont. Contrib., Vertebrata, art. 3, p. 63.

Remarks.—The Iowa specimens are poorly preserved, as secondary phosphatic deposition masks both the oral and aboral features. Only indistinct median longitudinal crests may be noted on the oral surface. The aboral plate is generally intact, but in some specimens it is partially broken thus exposing the cavity between the oral and aboral plates.

Occurrence.—In Iowa, the species was recovered from only the lowermost phosphatic member of the Maquoketa formation.

Repository.—Figured hypotype, S.U.I., 4859; and unfigured hypotypes, 4860.

AMORPHOGNATHUS TRIDIGITATA
Glenister, n. sp.
Pl. 88, fig. 22

The dental units of this species consist of 2 relatively straight bars, one branched and the other unbranched. These bars diverge from a blunt anterior apex at an angle of 45°. The shorter bar develops a branch at about one-fourth its length posteriorly from the apex, and the two components diverge at an angle of 45°. The convex oral plate is smooth; it has sharp margins and bears an elevated median longitudinal crest, which is more or less nodose. The aboral plate is flat.

Occurrence.—The species was recovered from only the lowermost phosphatic member of the Maquoketa formation in Iowa.

Repository.—Figured holotype, S.U.I., 4861.

Suborder CONODONTIFORMES Branson & Mehl, 1944
Family DISTACODIDAE Ulrich & Bassler, 1926
Genus DREPANODUS Pander, 1856
Type species: *D. arcuatus* Pander, 1856

Recent authors have been unable to agree in defining *Drepanodus* and *Oistodus* and differentiating between them. Lindström (1954, p. 557,558) has redefined both genera, and his description of *Drepanodus* is as follows:

> I have regarded all symmetrical or subsymmetrical species with smooth lateral faces, sharp anterior and posterior edges, and the posterior edge of the cusp meeting the oral margin in a curve, as belonging to *Drepanodus*.

DREPANODUS CF. D. ARCUATUS Pander
Pl. 86, fig. 8

Drepanodus cf. *arcuatus*, LINDSTRÖM, 1954, Geol. Foren. Forhandl., Bd. 76, H. 4, p. 560,561, pl. 2, fig. 45,46, text-fig. 4c.

Remarks.—The base develops a conical excavation, the apex of which is not distinctly inclined. The basal margin meets the oral margin at an acute angle. Most of the specimens have a cusp which is strongly recurved throughout its entire length. Transverse cross-sections of the cusp show a distinctly keeled anterior and a slightly keeled posterior face. The lateral faces are convex and are bilaterally sub-symmetrical. The basal outline is similar to that of the specimens of *D. arcuatus* figured by Pander (1856, Table 1, fig. 4b).

Occurrence.—In Iowa, this form was recovered from only the phosphatic member of the Maquoketa formation.

Repository.—Figured hypotype, S.U.I., 4862.

DREPANODUS CONCAVUS (Branson & Mehl)
Pl. 86, fig. 10

Oistodus concavus BRANSON & MEHL, 1933, Mo. Univ. Studies, vol. 8, no. 1, p. 59, pl. 4, fig. 6; FAY, 1952, Univ. Kansas Paleont. Contrib., Vertebrata, art. 3, p. 134.

Remarks.—The anterior basal extremity of the figured specimen has been broken. However, the undamaged basal outline almost certainly extended beyond the present rounded extremity to an anterior point.

Occurrence.—This species was recovered from only the phosphatic member of the Maquoketa formation in Iowa. Specimens were also identified from Stauffer's collections made at Spring Valley and Wykoff, Minnesota.

Repository.—Figured hypotype, S.U.I., 4863.

DEPANODUS HOMOCURVATUS Lindström
Pl. 86, fig. 13;
Pl. 87, fig. 1–6,8

Drepanodus homocurvatus LINDSTRÖM, 1954, Geol. Fören. Förhandl., Bd. 76, H. 4, p. 563, pl. 2, fig. 23,24,39.

Remarks.—This species includes a variety of forms which were previously referred by other authors to *Oistodus curvatus*. The curvature of the Iowa specimens varies slightly. All of the basal outlines have a general lachrymal shape, as the anterior portion is relatively narrow and expands posteriorly to a rounded or slightly keeled posterior outline. The basal outline of one figured specimen (Pl. 86, fig. 13) is heart-shaped. This results from the upward curvature of the anterior margin to the extent that it is concealed in the figure behind the central portion of the base. Transverse cross-sections of the cusps are generally biconvex posteriorly, and they are concavo-convex near the anterior margin. The anterior face is sharply keeled, whereas the posterior keel is much blunter.

Occurrence.—This species was recovered from the phosphatic, Elgin, Clermont and Ft. Atkinson members of the Maquoketa formation of Iowa. Specimens were also identified in the Maquoketa formation collections made at both Spring Valley and Wykoff, Minnesota.

Repository.—Figured hypotypes, S.U.I., 4864–4871.

DREPANODUS CF. D. SUBARCUATUS
Furnish
Pl. 86, fig. 9

Drepanodus subarcuatus FURNISH, 1938, Jour. Paleont., vol. 12, p. 320,328–330, pl. 41, fig. 25–32, pl. 42, fig. 2,3, text-fig. 1F, 1G; FAY, 1952, Univ. Kansas Paleont. Contrib., Vertebrata, art. 3, p. 90.

Remarks.—The basal outline of the Maquoketa specimens is lachrymal in shape, and it expands toward the rounded oral margin. A conical basal excavation has its apex located at the mid-width of the base. This apex points anteriorly. The cusp is strongly recurved at a short distance above the base, and it is then straight to the tip. Transverse cross-sections of the cusp show a sharp anterior keel and gently convex lateral faces. A slight keel is developed on the posterior face. The growth axis follows the curvature of the cusp, in some specimens, and it is straight in others.

Occurrence.—In Iowa, the species was recovered from the phosphatic member and the lower Elgin member of the Maquoketa formation.

Repository.—Figured hypotype, S.U.I., 4872.

Genus OISTODUS Pander, 1856
Type species: *O. lanceolatus*
Pander, 1856

Remarks.—Lindström (1954, p. 572,573) discussed Pander's original description of *Oistodus* and also the interpretations of this genus by subsequent authors. Uncertainty has developed in respect to the generic differences between *Oistodus* and *Drepanodus*. Lindström proposed the following redefinition, which will be used in this paper:

> To *Oistodus* belong simple conodonts with a more or less wide basal cavity. The posterior edge makes a sharp angle with the oral edge. As a rule, either or both of the lateral faces are carinate.

OISTODUS ABUNDANS Branson & Mehl
Pl. 86, fig. 5

Oistodus abundans BRANSON & MEHL, 1933, Mo. Univ. Studies, vol. 8, no. 2, p. 109, pl. 9, fig. 11,17; FAY, 1952, Univ. Kansas Paleont. Contrib., Vertebrata, art. 3, p. 134.

Remarks.—The base of the Iowa specimens is commonly broken, as is the cusp itself. However, the basal outline appears to vary only slightly from that of the figured specimen. The basal excavation is in many cases partly filled with matrix and thus gives the impression of being shallow.

Occurrence.—In Iowa, this distinctive species was recovered from over 90 per cent of the samples taken from the Elgin and Clermont members of the Maquoketa formation. Forms were also present in the Ft. Atkinson member of Iowa, and broken specimens were questionably identified in Stauffer's collection from Wykoff, Minnesota.

Repository.—Figured hypotype, S.U.I., 4873; and unfigured hypotypes, 4874.

OISTODUS EXCELSUS Stauffer
Pl. 86, fig. 4,7

Oistodus excelsus STAUFFER, 1935, Jour. Paleont., vol. 9, p. 610, pl. 74, fig. 43; FAY, 1952, Univ. Kansas Paleont. Contrib., Vertebrata, art. 3, p. 135.

Remarks.—In some of the Iowa specimens, the basal excavation is slightly deeper than the corresponding shallow grooves described by Stauffer. However, this excavation does not extend into the cusp. The outer-lateral face of the cusp is more regularly convex than the inner-lateral face, although the former is somewhat flattened at the margin. The inner-lateral face is flattened anteriorly, and the anterior keel may be slightly flexed inwardly. The basal outline of one of the figured specimens (Pl. 86, fig. 7) is heart-shaped. This results from the upturning of the anterior portion of the base, which is obscured behind the middle portion of the basal outline.

Occurrence.—In Iowa, this species was recovered from the phosphatic member of the Maquoketa formation. A specimen was also identified from the same formation at Spring Valley, Minnesota.

Repository.—Figured hypotypes, S.U.I., 4875,4876.

OISTODUS INCLINATUS Branson & Mehl
Pl. 86, fig. 11

Oistodus inclinatus BRANSON & MEHL, 1933, Mo. Univ. Studies, vol. 8, no. 2, p. 110, pl. 9, fig. 8; FAY, 1952, Kansas Univ. Paleont. Contrib., Vertebrata, art. 3, p. 135.

Remarks.—The basal outlines of the Maquoketa specimens exhibit a marked curvature of the anterior portion of the base toward the inner-lateral face. The cusp in some cases developed a shallow longitudinal carina which parallels the posterior marginal flattening on the inner side.

Occurrence.—In Iowa, the species was recovered from the phosphatic, Elgin and Clermont members of the Maquoketa formation.

Repository.—Figured hypotype, S.U.I., 4877.

OISTODUS PARALLELUS Pander
Pl. 86, fig. 1–3

Oistodus parallelus PANDER, 1856, Monographie der fossilen Fische des Silurischey Systems, p. 6,27, Tab. 2, fig. 40; FAY, 1952, Univ. Kansas Paleont. Contrib., Vertebrata, art. 3, p. 136; LINDSTRÖM, 1954, Geol. Fören. Förhandl., Bd. 76, H. 4, p. 579–580, pl. 4, fig. 26–31.

Remarks.—The specimens described by Lindström were used by that author to augment Pander's original work. Lindström noted the distinctive antero-basal angle. The anterior, and to a greater extent, the posterior portion of the base is commonly fractured in the Iowa specimens. Thus the Illustrated basal outlines are interpolations In the vicinity of the anterior and posterior extremities. Although *O. parallelus* has only hitherto been described from the Lower Ordovician, the Maquoketa forms seem to best fit this species, despite some slight variations. The cusps of the Iowa specimens exhibit the lateral deflection as well as the carinae illustrated by Lindström. The anterior face of the cusp may be straight or slightly sinuous. Within *O. abundans* Branson & Mehl (1933, p. 109) there have been included a variety of forms, one of which is figured by Stauffer (1935b, pl. 75, fig. 13). This figured specimen resembles some of the species illustrated in the present paper (Pl. 86, fig. 1–3). However, it is douftful if Stauffer's specimens fall within the originally defined scope of Branson & Mehl's species.

Occurrence.—In Iowa, the species was recovered from the phosphatic, Clermont, Ft. Atkinson, and lower Brainard members of the Maquoketa formation. Specimens were also identified from the Maquoketa formation at Spring Valley and Wykoff, Minnesota.

Repository.—Figured hypotypes, S.U.I., 4878–4880.

OISTODUS? SUBERECTUS Branson & Mehl
Pl. 86, fig. 12,14

Oistodus suberectus BRANSON & MEHL, 1933, Mo. Univ. Studies, vol. 8, no. 2, p. 111, pl. 9, fig. 7; FAY, 1952, Univ. Kansas Paleont. Contrib., Vertebrata, art. 3, p. 136.

Drepanodus suberectus LINDSTRÖM, 1954, Geol. Fören. Förhandl., Bd. 76, H. 4, p. 568, pl. 2, fig. 21,22.

Remarks.—Lindström (1954, p. 572,573) redefined the genus *Oistodus*, and he listed 6 species which he considered to belong to the revised taxon. He also stated that the remaining species referred to *Oistodus* should probably be included in *Drepanodus*. *O. suberectus* is one of the latter group of species. Its generic affinities have been considered, for the species is present in the author's collections. One form (Pl. 86, fig. 12) closely resembles the specimens of *O. suberectus*

figured in papers by various authors. These figured forms would be classified in Lindström's genus *Drepanodus*, as they lack the sharp angle between the oral margin of the base and the posterior margin of the cusp. The transverse cross-section of the cusp illustrates the sharp concave side and its keel development. This posteriorly constricted portion widens abruptly anteriorly, and it then tapers to a sharp anterior face. The expanded portions just anterior to the posterior keel, on the lateral faces, could be considered as blunt-edged carinae. Another specimen (Pl. 86, fig. 14) shows a more nearly angular junction between the cusp and the base. The cusp is sub-erect and bilaterally symmetrical. It lacks distinct lateral carinae. The basal outlines of both figured specimens are asymmetrical, although one of them (Pl. 86, fig. 12) approaches bilateral symmetry.

Occurrence.—In Iowa, the species was recovered from the phosphatic, Elgin, and Clermont members of the Maquoketa formation.

Repository.—Figured hypotypes, S.U.I., 4881,4882.

OISTODUS VENUSTUS Stauffer
Pl. 86, fig. 6

Oistodus venustus STAUFFER, 1935, Geol. Soc. Amer., Bull., vol. 46, p. 147,159, pl. 12, fig. 12; FAY, 1952, Univ. Kansas Paleont. Contrib,. Vertebrata, art. 3, p. 136.

Remarks.—Rhodes (1953, p. 295,296) considered that Stauffer's original description could be easily confused with those of such species as *O. abundans* Branson & Mehl. He assigned to *O. venustus* those forms which closely agree with the specific description and have the aboral margin equal in length to the cusp. The author has subdivided the group of Iowa specimens formally assigned to *O. abundans* into the two species mentioned above, using the distinction made by Rhodes and comparing the Maquoketa forms with Rhodes's (1953, pl. 22, fig. 168–170) text-figures. The lateral cusp faces of these specimens grade from smooth to longitudinally carinate. The posterior extension of the base is commonly broken in the Iowa specimens. Thus, the basal outline would project posteriorly beyond its illustrated limit.

Occurrence.—The species was recovered only from the phosphatic member of the Maquoketa formation in Iowa.

Repository.—Figured hypotype, S.U.I., 4883.

Genus PALTODUS Pander, 1856
Type species: *P. subaequalis* Pander, 1856

Remarks.—Since the original description of the genus (Pander, 1856, p. 24,91), subsequent authors have made many interpretations, which have led to the inclusion of forms that do not bear a close relationship to the type species. These variations have been discussed by Lindström (1954, p. 583), and he has redefined the genus as follows:

> To *Paltodus* belong simple, unsymmetrical, multicostate conodonts.

The present author accepts Lindström's redefinition, but includes within the genus only those forms which develop cross-sections similar to those figured by Pander (1856, Tab. A, fig. 4).

PALTODUS? ACOSTATUS Branson & Branson
Pl. 85, fig. 7

Paltodus acostatus BRANSON & BRANSON, 1947, Jour. Paleont., vol. 21, p. 554, pl. 82, fig. 1–5,23,24; FAY, 1952, Univ. Kansas Paleont. Contrib., Vertebrata, art. 3, p. 143.

Remarks.—Lindström proposed the genus *Scandodus* (1954, p. 592) to include the simple asymmetric conodonts which develop an anterior and posterior keel, but lack costae. *P. acostatus* would normally be included in this new taxon. However, Lindström described his new genus as lacking bilateral symmetry due to the twisting of the cusp relative to the base. He also noted a broadly rounded median carina on one side of the cusp. The author has found specimens of *P. acostatus* within her Maquoketa collections which exhibit the characteristic broad carina on each lateral face. A symmetrical excavation continues from the base for about two-thirds the length of the cusp. The inner-lateral face develops a groove along the posterior margin of the lateral carina. The outer-lateral face is smooth along the posterior portion and widens anteriorly onto the lateral carina. A sharp keel is developed on the anterior face and the posterior face is

slightly keeled. These forms are not twisted relative to the base, and some specimens develop faint costae on the lateral faces.

Occurrence.—In Iowa, the species was recovered from the phosphatic, Elgin, Clermont, and Ft. Atkinson members, and the limestone of the Brainard Member, of the Maquoketa Formation. A specimen is questionably referred to this species in Stauffer's collection from Spring Valley, Minnesota.

Repository.—Figured hypotype, S.U.I., 4884; and unfigured hypotypes, 4885.

PALTODUS FEULNERI Glenister, n. sp.
Pl. 85, fig. 11

The robust cusp is gently curved throughout, and it gradually narrows to a blunt tip. The base is not expanded. It is excavated by a conical opening that extends through two-thirds the cusp length. The anterior face is broadly rounded. It develops a median, longitudinal, blunt-edged keel, which begins immediately above the base. On the inner-lateral face, a rounded median carina is developed at the base, and it is bordered by a furrow on each side. These furrows are expressed as notches in the basal margin. Both the anterior keel and the lateral carina continue upward, but they lose their identity at about two-thirds the cusp length. The lateral faces are then gently convex to the tip. The anterior portion of the inner-lateral face is bordered by a sharp lateral offset costa, and the anterior side of this costa becomes part of the rounded anterior margin. The outer-lateral face is smooth and sinuous in transverse cross-section. A median logitudinal groove exists at the base, but becomes indistinct at about one-half the cusp length. The anterior portion of this face is marked by a lateral offset costa similar to that of the opposite side. The posterior face is moderately keeled.

Remarks.—The Maquoketa specimens are large and easily recognized.

Occurrence.—In Iowa, the species was recovered only from the limestone of the Brainard member of the Maquoketa formation.

Repository.—Figured holotype, S.U.I., 4886; and unfigured paratypes, 4887.

PALTODUS GRACILIS Branson & Mehl
Pl. 85, fig. 2–5

Paltodus gracilis BRANSON & MEHL, 1933, Mo. Univ. Studies, vol. 8, no. 2, p. 108, pl. 8, fig. 20,21; FAY, 1952, Univ. Kansas Paleont. Contrib., Vertebrata, art. 3, p. 144.

Remarks.—In this species have been included a variety of forms which have a gently convex anterior and sharp posterior margin. The posterior compressed portion of the cusp is separated from the rounded anterior part by a sharp offset on each lateral face. The Iowa specimens exhibit the characteristic cross-section (Branson, et al., 1951, p. 6, fig. 2A) in the upper three-fourths of the cusp. Diagrammatic cross-sections of the Maquoketa forms are presented (Pl. 85, fig. 2–5) to illustrate the variety of secondary costae which are developed posterior to the lateral offset on either or both lateral faces. These costae originate at or slightly above the base, and they continue longitudinally for a short distance upward.

Occurrence.—The species was recovered from the phosphatic, Elgin, Clermont, and Ft. Atkinson members, and the limestone of the Brainard member, of the Maquoketa formation in Iowa. Specimens were also identified from the collections at Spring Valley and Wykoff, Minnesota.

Repository.—Figured hypotypes, S.U.I., 4888–4891.

PALTODUS INTERMEDIUS Branson, Mehl & Branson
Pl. 85, fig. 10

Paltodus intermedius BRANSON, MEHL & BRANSON, 1951, Jour. Paleont., vol. 25, p. 7, pl. 1, fig. 9–15.

Remarks.—The type material is closely similar to the Iowa specimens.

Occurrence.—In Iowa, the species was recovered only from the limestone of the Brainard member of the Maquoketa formation.

Repository.—Figured hypotype, S.U.I., 4892; and unfigured hypotypes, 4893.

PALTODUS PANDERI Stauffer
Pl. 85, fig. 8,9

Paltodus panderi STAUFFER, 1940, Jour. Paleont., vol. 14, p. 427, pl. 60, fig. 8,9; FAY, 1952, Univ. Kansas Paleont. Contrib., Vertebrata, art. 3, p. 144.

The robust cusp of this species is gently curved in its lower portion, and it bends abruptly backward at mid-length. Above this posteriorly directed flexure, the cusp curves gently to the tip. The convex side is rounded onto the lateral faces. This curved surface becomes the anterior portion of an offset lateral costa on each face. In transverse cross-sections, these costae form the boundary between the wide anterior two-thirds of the cusp and the posterior compressed portion. The costae begin at the base, and they continue to the broken tips of the specimens. They are not identical in either position or form; the inner-lateral costa is generally sharper than the outer-lateral equivalent. There may be secondary longitudinal costae developed on the posterior compressed portion of the lateral faces. The posterior margin of the cusp is rounded. The basal outline is a modified pattern of the cusp transverse cross-section. It is compressed in the posterior one-third, where it coincides with the lateral constriction of the cusp above. A single conical excavation of the base may only extend to the cusp flexure, or it may continue to the distal part of the bend. A double excavation was noted in some forms; one cavity extends into the wider portion of the cusp, and a shorter cone is located in the posteriorly constricted portion.

Remarks.—Some of the Iowa specimens are more laterally compressed than the figured forms, and they develop sharper anterior and posterior faces. The offset of the lateral costae is not large, and these forms tend to lose the distinct difference between the rounded anterior and the compressed posterior portions of the cone.

Occurrence.—In Iowa, the species was recovered from all 5 members of the Maquoketa formation. Specimens were also identified from the same formation at Spring Valley and Wykoff, Minnesota.

Repository.—Figured hypotypes, S.U.I., 4894,4895.

PALTODUS STRIATUS Stauffer
Pl. 85, fig. 6

Paltodus striatus STAUFFER, 1935, Jour. Paleont., vol. 9, p. 613, pl. 74, fig. 3,16; FAY, 1952, Univ. Kansas Paleont. Contrib., Vertebrata, art. 3, p. 144.

Remarks.—In some of the Maquoketa specimens, the rounded keel on the concave side of the cone is bounded by a shallow furrow, which is discernible on one lateral face only. On the opposite face, a small anterior lateral costa begins slightly above the base, and it diminishes rapidly at about two-thirds the cone length. Both lateral faces exhibit minute longitudinal striae.

Occurrence.—The species was recovered from the Elgin, Clermont, and Ft. Atkinson members of the Maquoketa formation in Iowa.

Repository.—Figured hypotype, S.U.I., 4896.

PALTODUS? UNICOSTATUS
Branson & Mehl
Pl. 85, fig. 1

Paltodus unicostatus BRANSON & MEHL, 1933, Mo. Univ. Studies, vol. 8, no. 1, p. 42, pl. 3, fig. 3; FAY, 1952, Univ. Kansas Paleont. Contrib., Vertebrata, art. 3, p. 144.

Remarks.—Lindström (1954, p. 583) redefined the genus *Paltodus* to include only the multicostate asymmetrical forms. To the genus *Acodus* he brought the unicostate species. Following Lindström, *P. unicostatus* should then be referred to *Acodus*, as the original description by Branson & Mehl (1933, p. 42) denotes only one distinct lateral costa. Rhodes (1953, p. 298, pl. 21, fig. 84–88; pl. 22, fig. 155,156; pl. 23, fig. 214–216) illustrates a gradation in form for this species, from a robust cone to a slender type. The author has recovered forms which vary only slightly in transverse cross-section and which are generally of the more slender type.

Occurrence.—In Iowa, the species was recovered from all 5 members of the Maquoketa formation. Specimens were also identified from the same formation at Spring Valley and Wykoff, Minnesota.

Repository.—Figured hypotype, S.U.I., 4897; and unfigured hypotypes, 4898.

Family PRIONIODIDAE Ulrich & Bassler, 1926
Genus BELODUS Pander, 1856
Type species: *B. gracilis* Pander, 1856
BELODUS DISPANSUS Glensiter, n. sp.
Pl. 88, fig. 14,15

The basal cone is relatively long, slender,

and bilaterally symmetrical. It is gently curved orally. The base does not appear to be laterally compressed, and it may develop a forward flange. The transverse cross-section of the base is narrow orally; it expands at about mid-height and narrows towards the blunt edge of the inferior margin. In larger specimens a flat lateral ridge begins along the inferior margin at about mid-length of the cone, and it continues anteriorly. The lateral curvature of the basal cone diminishes rapidly forward of the oral denticulation, and the specimens become gently convex near the tip. Minute longitudinal striations cover the lateral faces from base to tip. The anterior two-thirds of the basal cone is compressed and sharp-edged; it tapers to a sharp point. The oral edge is set with from 7 to 14 small, sharp, confluent denticles, which are inclined forward.

Occurrence.—In Iowa, the species was recovered from the Elgin and Clermont members of the Maquoketa formation.

Repository.—Figured syntypes, S.U.I., 4899,4900.

BELODUS ORNATUS Branson & Mehl
Pl. 87, fig. 7,9a,b,10

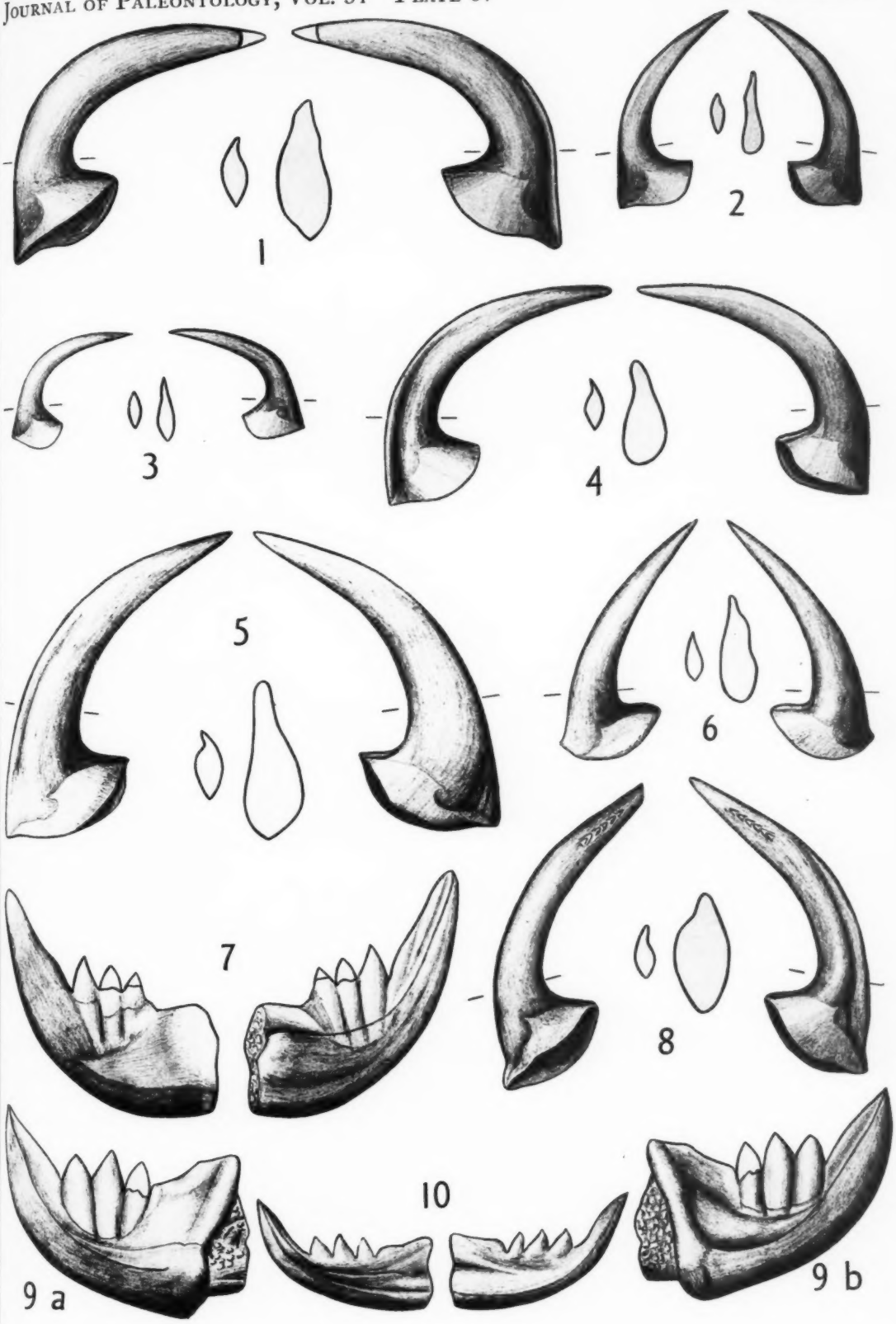
Belodus ornatus BRANSON & MEHL, 1933, Mo. Univ. Studies, vol. 8, no. 2, p. 124,125, pl. 10, fig. 26,28; FAY, 1952, Kansas Univ. Paleont. Contrib., Vertebrata, art. 3, p. 67.

Remarks.—The Maquoketa specimens of *Belodus* are gradational in morphology. The inner face may lack ornamentation so that it is nearly in a plane (Pl. 87, fig. 7). However, it may develop a longitudinal depression at about mid-height of the cusp. This depression is bordered aborally by an offset costa (Pl. 87, fig. 9b). Intermediate forms have no depression, but they bear an offset costa along the aboral margin of the cone (Pl. 87, fig. 10). The outer face develops a narrow groove at about mid-height of the cusp (Pl. 87, fig. 7). This groove is situated above a deeper longitudinal depression, and the two elements may fuse at about mid-length in some specimens (Pl. 87, fig. 10). In other specimens the adoral groove is extremely shallow, and it is situated in the flank of the longitudinal depression (Pl. 87, fig. 9a). Specimens which exhibit the deep longitudinal depression, possess a distinct offset costa beneath it. Other specimens lack the depression, and their planular faces widen aborally onto blunt-edged carinae. These facial configurations are best developed immediately anterior to the base, and they decrease rapidly towards the tip. Many robust specimens exhibit a forward flange on the base. The portion of the basal cusp forward of the oral denticulation also forms an oral flange, which may become pronounced in some specimens. However, the basal flange is more commonly observed on the specimens than is the cusp flange. The oral edge of the cusp is set with 3 to 4 peg-like denticles, which have the appearance of being wedged-in between the basal and cusp flanges. They penetrate deep into the cusp, and emerge with confluent edges. These denticles narrow abruptly near their tips. The denticle adjacent to the base is generally the smallest of the set. This denticle appears to be confluent with the basal flange. Stauffer (1935b, p. 603,604) noted in his specimens of *B. grandis*, that denticles are added at both ends of the series. The denticles of *B. dispansus* (Pl. 88, fig. 14,15) become progressively larger forward of the base. The possibility of addition of denticles at either end of the series seems quite plausible in the Maquoketa species. However, the strongest evidence is for the addition of denticles at

EXPLANATION OF PLATE 87

FIG. *1–6,8*—*Drepanodus homocurvatus* Lindström, ×40. *1*, Phosphatic member, Locality 4, hypotype (4865); *2*, Clermont member, Locality 5, hypotype (4866); *3*, Clermont member, Locality 5, hypotype (4867); *4*, Uppermost Clermont member, Locality 5, hypotype (4868); *5*, Clermont member, Locality 1, hypotype (4869); *6,8*, phosphatic member, Locality 4, hypotypes (4870, 4871).

7,9,10—*Belodus ornatus* Branson & Mehl, ×55. *7*, Lowermost Clermont member, Locality 5, hypotype (4901); *9a*, Outer-lateral view, and *9b*, inner-lateral view, Clermont member, Locality 1, hypotype (4902); *10*, Clermont member, Locality 8, hypotype (4903).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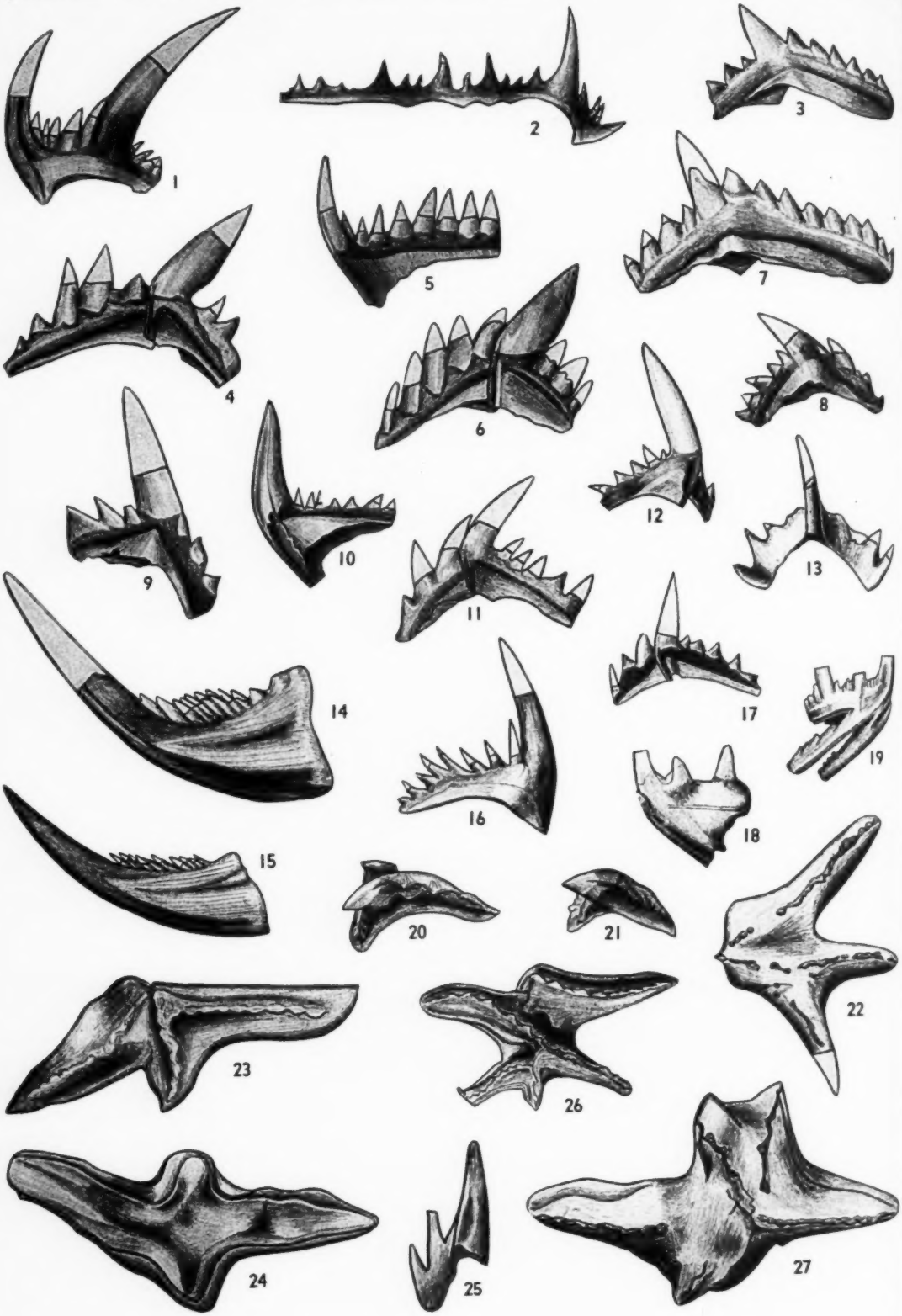
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the basal end. None of the morphological variations of *B. ornatus* appear to be restricted to any one member of the Maquoketa formation in Iowa. Certain of the morphological variants in the Iowa specimens, herein referred to *B. ornatus*, bear affinities with *B. diminutivus* Branson & Mehl (1933, p. 125, pl. 10, fig. 27). However, it is possible that the differences between *B. ornatus* and *B. diminutivus* are largely due to ontogenetic development. With this in mind, the present author has allowed considerable variation within this species.

Occurrence.—In Iowa, the species was recovered from the Elgin, Clermont, and Ft. Atkinson members of the Maquoketa formation. Two specimens were found in C. R. Stauffer's collection from Spring Valley, Minnesota.

Repository.—Figured hypotypes, S.U.I., 4901–4903.

Genus CORDYLODUS Pander, 1856

Type species: *C. angulatus* Pander, 1856

Remarks.—The author has treated *Subcordylodus* Stauffer (1935a, p. 153) as a junior subjective synonym of *Cordylodus* Pander (1856, p. 33,90) in view of the comments made by Rhodes (1953, p. 301) and Fay (1952, p. 82,205), with which she is in full accord.

CORDYLODUS? DELICATUS
Branson & Mehl
Pl. 88, fig. 5

Cordylodus? delicatus BRANSON & MEHL, 1933, Mo. Univ. Studies, vol. 8, no. 2, p. 129, pl. 10, fig. 14,15; FAY, 1952, Univ. Kansas Paleont. Contrib., Vertebrata, art. 3, p. 82.

Remarks.—The posterior denticles of the Iowa specimens are commonly broken. They appear to be either sub-erect or inclined posteriorly. The denticulation of the posterior

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EXPLANATION OF PLATE 88

All figures, ×55

FIG. *1,2—Phragmodus undatus* Branson & Mehl. *1*, Lateral view, Clermont member, Locality 5, hypotype (4910); *2*, Lateral view, Elgin member, Locality 7, hypotype (4911).

3,7—Ozarkodina inclinata. Glenister, n. sp. *3*, Lateral view, phosphatic member, Locality 4, syntype (4926); *7*, Lateral view, Wykoff, Minnesota, syntype (4927).

4,6—Dichognathus typica Branson & Mehl. *4*, Outer-lateral view, lowermost Clermont member, Locality 5, hypotype (4922); *6*, Outer-lateral view, Clermont member, Locality 5, hypotype (4923).

5—Cordylodus? delicatus Branson & Mehl. Inner-lateral view, Spring Valley, Minnesota, hypotype (4904).

8,9—Ozarkodina delecta Stauffer. Lateral views. *8*, Phosphatic member, Locality 4, hypotype (4924); *9*, Wykoff, Minnesota, hypotype (4925).

10,12—Dichognathus brevis Branson & Mehl. *10*, Inner-lateral view, Elgin member, Locality 7, hypotype (4918); *12*, Outer-lateral view, Elgin member, Locality 8, hypotype (4919).

11,17—Dichognathus extensa Branson & Mehl. Outer-lateral views. *11*, Lower Clermont member, Locality 1, hypotype (4920); *17*, Elgin member, Locality 3, hypotype (4921).

13—Trichonodella flexa Rhodes. Posterior view, phosphatic member, Locality 4, hypotype (4916).

14,15—Belodus dispansus Glenister, n. sp. Lateral views. *14*, Lowermost Clermont member, Locality 5, syntype (4899); *15*, Elgin member, Locality *8*, syntype (4900).

16—Cyrtoniodus complicatus Stauffer. Inner-lateral view, phosphatic member, Locality 4, hypotype (4907).

18—Cordylodus primus Branson & Mehl. Inner-lateral view, phosphatic member, Locality 4, hypotype (4905).

19—Roundya inclinata (Rhodes). Lateral view, phosphatic member, Locality 4, hypotype (4914),

20,21—Ambalodus triangularis Branson & Mehl. Inner-lateral views, phosphatic member, Locality 4, hypotypes (4852, 4853).

22—Amorphognathus tridigitata Glenister, n. sp. Oral view, phosphatic member, Locality 4, holotype (4861).

23,24—Amorphognathus adunca Glenister, n. sp. Phosphatic member, Locality 4. *23*, Oral view, syntype (4854); *24*, aboral view, syntype (4855).

25—Ligonodina sp. Posterior view, phosphatic member, Locality 4, specimen (4908).

26—Amorphognathus complicata Rhodes. Oral view, phosphatic member, Locality 4, hypotype (4857).

27—Amorphognathus ramosa (Stauffer). Oral view, phosphatic member, Locality 4, hypotype (4859).

bar increases in size away from the apical denticle. In this respect, the specimens closely resemble *Cordylodus rectilineatus* (Stauffer) (1935a, p. 154,160, pl. 11, fig. 30,32).

Occurrence.—In Iowa, the species was recovered from the phosphatic, Elgin, and lower Clermont members of the Maquoketa formation. Specimens were also identified in Stauffer's collections from Spring Valley and Wykoff, Minnesota.

Repository.—Figured hypotype, S.U.I., 4904.

CORDYLODUS PRIMUS Branson & Mehl
Pl. 88, fig. 18

Cordylodus primus BRANSON & MEHL, 1933, Mo. Univ. Studies, vol. 8, no. 1, p. 35, pl. 1, fig. 35; FAY, 1952, Univ. Kansas Paleont. Contrib., Vertebrata, art. 3, p. 82,83.

Remarks.—The oral edge of the expanded base is broken in all known Maquoketa specimens, but it retains 2 to 3 widely separated denticles. These denticles are broken and abraded. The denticle immediately posterior to the cusp is distinctly smaller than the cusp. However, the denticles increase in size posteriorly until they almost equal the dimensions of the cusp. The posterior denticles taper rapidly.

Occurrence.—In Iowa, the species was recovered only from the phosphatic member of the Maquoketa formation.

Repository.—Figured hypotype, S.U.I., 4905, and unfigured hypotype, 4906.

Genus CYRTONIODUS Stauffer, 1935
Type species: *C. complicatus* Stauffer, 1935

CYRTONIODUS COMPLICATUS Stauffer
Pl. 88, fig. 16

Cyrtoniodus complicatus STAUFFER, 1935, Geol. Soc. Amer., Bull., vol. 46, p. 140,158, pl. 11, fig. 44,46,48–51; FAY, 1952, Univ. Kansas Paleont. Contrib., Vertebrata, art. 3, p. 85; RHODES, 1953, Phil. Trans. Roy. Soc. London, ser. B, no. 647, vol. 237, p. 302, pl. 22, fig. 193–196.

Remarks.—Rhodes noted the similarity between *Cyrtoniodus complicatus* and *Prioniodus? flexuosus* Branson & Mehl (1933, p. 130, pl. 10, fig. 16). The Iowa specimens fall within Rhodes's elaborated description of the former species.

Occurrence.—In Iowa, the species was recovered only from the phosphatic member of the Maquoketa formation. Specimens were also identified from the same formation at Spring Valley and Wykoff, Minnesota.

Repository.—Figured hypotype, S.U.I., 4907.

Genus LIGONODINA Ulrich & Bassler, 1926
Type species: *L. pectinata* Ulrich & Bassler, 1926

Remarks.—*Eoligonodina* Branson, Mehl & Branson (1951, p. 14,15) closely resembles *Ligonodina*, but the former develops a deep excavation below the anterior fang. *Eoligonodina* was based on Upper Ordovician specimens. The oldest known occurrence of *Ligonodina* was from the middle Silurian, but Rhodes (1953, p. 305) discussed the two genera and included 4 new species from the Lower Paleozoic in *Ligonodina*. These new species include Upper Ordovician forms.

LIGONODINA sp.
Pl. 88, fig. 25

Remarks.—The terminology used in this description is that of Rhodes (1953, p. 305, fig. 11). The anterior fang is short, and it is slightly curved posteriorly. In lateral view, it has a gently convex anterior side, and a moderately concave posterior side. The fang tapers rapidly to a sharp point. The anterior face is flat, and it is flanked by a distinct longitudinal carina along the anterior portion of each lateral face. A blunt longitudinal keel is situated along the posterior face. Thus, the anterior fang has a T-shaped transverse cross-section. All the specimens in the author's collection have an anteroinferior process, which bears 2 widely separated sub-circular denticles. They taper to a sharp point, and are inclined so as to be subparallel to the anterior fang. The process is commonly broken, and it is probable that more denticles are present in complete specimens.

Occurrence.—In Iowa, the species was recovered from the phosphatic member of the Maquoketa formation.

Repository.—Figured specimens, S.U.I., 4908; and unfigured specimen, 4909.

Genus PHRAGMODUS Branson & Mehl, 1933

Type species: *P. primus* Branson & Mehl, 1933

PHRAGMODUS UNDATUS Branson & Mehl

Pl. 88, fig. 1,2

Phragmodus undatus BRANSON & MEHL, 1933, Mo. Univ. Studies, vol. 8, no. 2, p. 115,116, pl. 8, fig. 22–26; FAY, 1952, Univ. Kansas Paleont. Contrib., Vertebrata, art. 3, p. 146.

Remarks.—The Maquoketa specimens of Iowa show considerable variation. The lower anterior denticle may be laterally compressed and sharp-edged. A carina is developed on one or both lateral faces. More robust specimens exhibit a flattening of the anterior face of the denticle. This flat zone is bordered by a distinct costa on each lateral face. The posterior edge is keeled, and thus the denticle has a T-shaped or triangular transverse cross-section. The ornamentation of the lateral faces is well developed in the base, and it disappears at about two-thirds the denticle length. An aboral projection of the lower anterior denticle forms the anterior margin of the base. The basal excavation is bounded by the aboral projection of this denticle, the denticulate oral surface, and the lateral sheath lamellae. It is deepest beneath the oral portion bounded by the lower and upper anterior denticles, and it coverges to an anteriorly directed apex beneath the lower anterior denticle. Less robust specimens do not show a basal apex. This excavation decreases rapidly to a shallow groove in the oral bar. Most of the Iowa specimens demonstrate the deeply concave aboral margin, but the base is frequently broken. Some specimens, not figured in this paper, exhibit sheath lamellae which extend far below the aboral projection of the lower anterior denticle, and which enclose a deep cavity beneath the entire specimen. Succeeding the lower anterior denticle are from 2 to 5 smaller, laterally compressed denticles, which increase in size progressively toward the upper anterior denticle. In some specimens there are 2 conspicuously larger denticles adjacent to the upper anterior position. In other specimens, the upper anterior denticle is singularly larger than those adjacent to it, and it may surpass the lower anterior denticle in size. Both the lower and upper anterior denticles are inclined posteriorly, and they are sub-parallel. The oral bar is sinuous, and it develops symmetrical lateral curves. A series of small, subequal denticles is interrupted by a large denticle at the crest of each curve. The more robust specimens have an almost straight bar; this bar develops little denticle differentiation, although slightly larger denticles are separated by 3 or 4 smaller denticles. The denticulations of the oral bar are laterally compressed, and they form sharp anterior and posterior edges.

The lower anterior denticle and the posterior denticulation of the syntypes of *P. undatus* Branson & Mehl (1933, pl. 8, fig. 22–24) closely resemble those paratypes and syntypes figured by Stauffer (1935a, pl. 11, fig. 9,15–17,19–22,25,26,34) for *P. inflexus*. However, the oral bars seem to differ.

Occurrence.—In Iowa, the species was recovered from all 5 members of the Maquoketa formation.

Repository.—Figured hypotypes, S.U.I., 4910,4911; and unfigured hypotypes, 4912, 4913.

Genus ROUNDYA Hass, 1953

Type species: *R. barnettana* Hass, 1953

Remarks.—Hass (1953, p. 88–90) emended the genus *Trichonodella* to include only those forms which have a non-denticulate posterior bar. He proposed the genus *Roundya* to include those species, formerly assigned to *Trichonodella*, that develop denticulation on the posterior bar.

ROUNDYA INCLINATA (Rhodes)

Pl. 88, fig. 19

Trichonodella inclinata RHODES, 1953, Phil. Trans. Roy. Soc. London, ser. B, no. 647, vol. 237, p. 315, pl. 22, fig. 176,177,186.

Roundya inclinata RHODES, 1955, Quart. Jour. Geol. Soc. London, vol. 111, pt. 2, no. 442, p. 137.

Remarks.—The apical denticle curves gradually backward to the tip from the point of conjugation with the lateral bars. The denticles of the lateral bars and the apical denticle are usually broken. However, the bar denticulation appears to be subparallel to the lower portion of the apical denticle. In some specimens, the posterior bar develops a slight oral arch close to the apical denticle, but it is straight in its posterior portion. The "hindeodellid" denticu-

lation varies from erect to sub-parallel to the lower curvature of the apical denticle. All 3 bars are commonly broken in the Iowa specimens.

Occurrence.—In Iowa, the species was recovered from the phosphatic member of the Maquoketa formation. Another specimen was identified in Stauffer's collection from Spring Valley, Minnesota.

Repository.—Figured hypotype, S.U.I., 4914; and unfigured hypotypes, 4915.

Genus TRICHONODELLA Branson & Mehl, 1948
[=*Trichognathus* Branson & Mehl, 1933]
Type species: *T. prima* (Branson & Mehl), 1933

Remarks.—Hass (1953, p. 89, 90) redefined *Trichonodella* to include only those forms which have a non-denticulate posterior bar.

TRICHONODELLA FLEXA Rhodes
Pl. 88, fig. 13

Trichonodella flexa RHODES, 1953, Phil. Trans. Roy. Soc. London, ser. B, no. 647, vol. 237, p. 313,314, pl. 22, fig. 181–183,188,189,191,192.

Remarks.—Iowa specimens are poorly preserved. The posterior basal expansion of the apical denticle is broken, and it can not be properly studied. However, the lower portion of the apical denticle and the denticulation of the lateral bars conform to the original description.

Occurrence.—The species was recovered from only the phosphatic member of the Maquoketa formation in Iowa.

Repository.—Figured hypotype, S.U.I., 4916; and unfigured hypotype, 4917.

Family PRIONIODINIDAE Ulrich & Bassler, 1926
Genus DICHOGNATHUS Branson & Mehl, 1933
Type species: *D. prima* Branson & Mehl, 1933

DICHOGNATHUS BREVIS Branson & Mehl
Pl. 88, fig. 10,12

Dichognathus brevis BRANSON & MEHL, 1933, Mo. Univ. Studies, vol. 8, no. 2, p. 113, pl. 9, fig. 24–26; FAY, 1952, Univ. Kansas Paleont. Contrib., Vertebrata, art. 3, p. 86.

The base is composed of short, straight bars which form an arch of about 90°. The basal excavation is deep and conical below the apical denticle, but it decreases rapidly to a rather shallow groove along the aboral margin of the bars. An exceptional lateral offset of the apical denticle, on the outer face, is matched by a distinct convexity on the inner face. The anterior bar bears up to 8 short, laterally compressed, sharp-pointed denticles. The denticulation of the posterior bar is not as well developed. The apical denticle is exceptionally long in relation to the bars. It is laterally compressed, is sharp-edged, and it has gently convex lateral faces. This denticle is relatively straight above a sharp bend located at its union with the bars.

Remarks.—The apical denticle, the bars, and a portion of the aboral margin are commonly broken from the Iowa specimens. However, the bars seem to taper rapidly, and they appear to be relatively short.

Occurrence.—In Iowa, the species was recovered from all 5 members of the Maquoketa formation.

Repository.—Figured hypotypes, S.U.I., 4918,4919.

DICHOGNATHUS EXTENSA Branson & Mehl
Pl. 88, fig. 11,17

Dichognathus extensa BRANSON & MEHL, 1933, Mo. Univ. Studies, vol. 8, no. 2, p. 114, pl. 9, fig. 21; FAY, 1952, Univ. Kansas Paleont. Contrib., Vertebrata, art. 3, p. 86.

The base is long and narrow. The aboral and oral margins are sub-parallel, but the base increases in depth below the apical denticle. The lateral offset of the apical denticle is slight, and it is expressed at the aboral margin as a small lateral flare. A slight convexity along the aboral edge at the apical denticle marks the otherwise smooth inner face. Both of the bars are thin. The anterior bar has 3 sharp-edged, pointed denticles, which are confluent in their lower portions. Posterior bar denticulation consists of 7 smaller denticles, similar to those of the anterior bar. The apical denticle is comparatively short. It is laterally compressed and is inclined posteriorly.

Remarks.—The author has partly based her classification of the Iowa specimens upon the narrow base and the slight offset of the apical denticle. The anterior bar is shorter than the posterior bar. However, it bears

larger denticles. Both bars are invariably broken in all the Maquoketa specimens studied from Iowa.

Occurrence.—In Iowa, the species was recovered from the Elgin, Clermont, and Ft. Atkinson members, and the shale of the Brainard member, of the Maquoketa formation.

Repository.—Figured hypotypes, S.U.I., 4920,4921.

DICHOGNATHUS TYPICA Branson & Mehl
Pl. 88, fig. 4,6

Dichognathus typica BRANSON & MEHL, 1933, Mo. Univ. Studies, vol. 8, no. 2, p. 113,114, pl. 9, fig. 27–29; STAUFFER, 1935, Geol. Soc. Amer., Bull., vol. 46, p. 141,159, pl. 11, fig. 2,3,5,8,10; FAY, 1952, Univ. Kansas Paleont. Contrib., Vertebrata, art. 3, p. 86.

Remarks.—The denticles of some of the Maquoketa specimens are confluent in their lower portions.

Occurrence.—In Iowa, this species was recovered from the Elgin, Clermont, and Ft. Atkinson members, and the shale of the Brainard member, of the Maquoketa formation.

Repository.—Figured hypotypes, S.U.I., 4922,4923.

Genus OZARKODINA Branson & Mehl, 1933
Type species: *O. typica* Branson & Mehl, 1933

OZARKODINA DELECTA Stauffer
Pl. 88, fig. 8,9

Ozarkodina delecta STAUFFER, 1935, Geol. Soc. Amer., Bull., vol. 46, p. 148,159, pl. 10, fig. 40; FAY, 1952, Univ. Kansas Paleont. Contrib., Vertebrata, art. 3, p. 137.

Remarks.—The anterior bar denticulation of the Iowa specimens is larger than that of the posterior bar. It increases in size towards the apical denticle. The denticles on the posterior bar grow progressively larger away from the apical denticle.

Occurrence.—In Iowa, this species was recovered only from the phosphatic member of the Maquoketa formation. Specimens were also identified from Wykoff and Spring Valley, Minnesota.

Repository.—Figured hypotypes, S.U.I., 4924,4925.

OZARKODINA INCLINATA Glenister, n. sp.
Pl. 88, fig. 3,7

Dental units of this species are composed of 2 relatively straight bars, which meet to form an angle of approximately 130°. The anterior bar is slightly longer and more developed than the posterior bar. Its aboral edge is deeply excavated and flared laterally. This lateral flare is most pronounced beneath the apical denticle, where it forms a more or less conical sub-apical naval. The basal excavation begins as a shallow groove in the posterior bar, and it increases in depth into the anterior bar. It tapers rapidly at the anterior end. In some specimens, the oral margin of the aboral excavation penetrates into the lowermost part of the individual denticles, so that it appears sub-denticulate in outline. The apical denticle is about twice the average size of the bar denticulation. It has slightly convex lateral faces with sharp edges, and it is inclined posteriorly. The anterior bar has from 6 to 9 short, sub-equal, sharp-pointed denticles, which are confluent at their bases. They increase slightly in size towards the apical denticle. The posterior bar bears from 2 to 4 denticles which are similar in form to those of the anterior bar. One denticle, adjacent to the apical denticle, is slightly smaller than the others. The denticulation of both bars is sub-parallel to the apical denticle.

Remarks.—The anterior bar of the Iowa specimens is commonly broken.

Occurrence.—In Iowa, the species was recovered only from the phosphatic member of the Maquoketa formation. Specimens were also identified in Stauffer's collections from Wykoff and Spring Valley, Minnesota.

Repository.—Figured syntypes, S.U.I., 4926,4927; and unfigured syntypes, 4928.

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LATE MISSISSIPPIAN FAUNA FROM THE REDOAK HOLLOW FORMATION OF SOUTHERN OKLAHOMA
PART 3. PELECYPODA

MAXIM K. ELIAS
University of Nebraska, Lincoln

ABSTRACT—The new genus *Eopleurophorus* and the new subgenus *Springeria* are introduced, and thirty-seven species and subspecies are described, seventeen of which are new. Some forms show apparent relation to British Lower Carboniferous species, but the majority are related to American Mississippian and Pennsylvanian forms.

Morphology and taxonomic status of the genera *Solen, Edmondia, Nuculopsis, Phestia, Polidevcia, Yoldia, Parallelodon, Leptodesma, Pteronites, Sedgwickia, Schizodus, Sanguinolites, Allorisma, Tellinomorpha,* and *Pleurophorus* are discussed.

GENERAL DISCUSSION

IF COMPARISON were made only with the pelecypods known in the Carboniferous of America the forms of this group in the Redoak Hollow would have shown an overwhelming affinity to the Pennsylvanian rather than to the Mississippian forms (Table 1). But as soon as the European Carboniferous pelecypods are taken into account this picture of affinities changes perceptibly, as there is a remarkably large number of the pelecypods that are identical or closely related to the Lower Carboniferous forms from the British Isles. Particularly clear is this re-

TABLE 1—COMPARISON OF THE PELECYPODS FROM THE REDOAK HOLLOW WITH FORMS STRATIGRAPHICALLY BELOW AND ABOVE THEM

Mississippian	Redoak Hollow Formation	Pennsylvanian
S. (Solenopsis) scalpriformis Winchell	*Solen (Solenomorpha?) gardneri*, n. sp.	*S. (Solenomorpha?) solenoides* (Geinitz)
Solen (?) *nitida* Girty	*Solen* (?) *nitida* (Girty)	
S. (P.) meeki Winchell	*Solen (Prothyris) soleniformis*, n. sp.	*S. (P.)* aff. *meeki* Winchell
E. rudis (McCoy)	*Edmondia* cf. *senilis* (Phillips)	*E.* cf. *gibbosa* (McCoy)
E. haimeanus de Koninck	*Edmondia splendens*, n. sp.	*E. ovata* Meek and Worthen
N. rectangula McChesney	*Nucula anodontoides* var. *minuta*, n. subsp.	*N. anodontoides ?* Meek
	Nucula subventricosa, n. sp.	*N. ventricosa* (Hall)
P. vaseyana McChesney	*Phestia inflata* (Girty, Morningstar)	*P. inflata* (Girty, Morningstar)
P. vaesyana McChesney	*Polidevcia* cf. *vaseyana* Girty	*P. bellistriata* Stevens
	Yoldia (Orthoyoldia) glabra Beede and Rogers	*Y. glabra* Beede and Rogers
P. concinnus M'Coy	*Parallelodon vokesi*, n. sp.	*P. cancellatus* Mather
C. meekanum Hall	*Conocardium*, sp. A	*C. parriski* (Worthen)
C. irregulare (de Koninck)	*Conocardium sayrei*, n. sp.	*C. parriski* Worthen
L. lunulata (Phillips)	*Leptodesma (Springeria) matheri*, n. sp.	*L. matheri* (?) n. sp.
L. thompsoni Hind	*Leptodesma (Springeria) stenzeli*, n. sp.	
L. longirostris Hind	*Leptodesma* n. sp. B	
P. angustus McCoy	*Pteronites* cf. *angustatus* McCoy	*Aviculopinna americanus* Meek
S. scotica Hind	*Sedgwickia rugosa*, n. sp.	*S. (?) topekaensis* (Shumard)
S. chesterensis Meek and Worthen	*Schizodus chesterensis* Meek and Worthen	*S. wheeleri* (Swallow)
A. chesterensis Worthen	*Aviculopecten tomlinsoni*, n. sp.	*A. halensis* Mather
A. dissimilis (Fleming)	*Aviculopecten* n. sp. C	
	Limipecten newelli, n. sp.	*L. morsei* Newell
	Acanthopecten grandis, n. sp.	*A. carboniferous* (Stevens)
	Streblochondria (?) tenuilineata (Meek and Worthen)	*S. tenuilineata* (Meek and Worthen)
	Euchondria subquadrata, n. sp.	*E. levicula* Newell
Paleolima chesterensis (Worthen)	*Paleolima inequicostata* Mather	*P. inequicostata* Mather
S. (?) omalianus de Koninck	*Sanguinolites omalianus* de Koninck	*S. (?) costata* (Meek and Worthen)
S. tricostatus (Portlock)	*Sanguinolites raleighensis* Price	*S. raleighensis* Price
S. ovalis Hind	*Sanguinolites* sp. D	
S. striato-lamellosus de Koninck	*Sanguinolites* (?) sp. E	
A. sulcata (Fleming)	*Allorisma maynardwhitei*, n. sp.	
A. sniderí n. sp.	*Allorisma sniderí*, n. sp.	*A. terminale* Hall
T. cuneiformis de Koninck	*Tellinomorpha schencki*, n. sp.	
	Eopleurophorus cf. *spinulosa* Morningstar	*E. spinulosa* Morningstar
	Eopleurophorus immaturus Herrick	*E. immaturus* Herrick
	Astartella (?) aff. *concentrica* Conrad	*A. concentrica* Conrad
C. oblonga Hall	*Cypricardella (?) enigmatica* n. sp.	*C. oblonga (?)*

Note: Solid lines indicate identity or close relationship of the species; dotted lines indicate their more distant relationships.

lationship for the species of *Leptodesma* (*Springeria*) and *Pteronites*, and for the species of *Schizodus*-like shells, among which can be clearly recognized representatives of western European Lower Carboniferous genera *Sedgwickia*, *Sanguinolites*, and *Tellinomorpha*. By comparison with this sudden(?) influx of western European pelecypods there is a surprisingly small number of species (four) which survived into Redoak Hollow time with but little, if any, change from Mississippian inland seas of America. As to the very large number (fifteen) of pelecypods which can be placed easily in the ancestry of our common Pennsylvanian forms, but whose origin is not so easy to establish—their seemingly sudden appearance in the Redoak Hollow may be most logically explained by the present inadequacy of our knowledge of American late Mississippian pelecypods, particularly in the type-area of the Chester. About all that we know on the Chester pelecypods dates back to Worthen's descriptions of a few species in 1890, illustrated by sketches much too incomplete and generalized as compared with the present paleontological standards. Recent work by Easton on the Pitkin of Arkansas includes a list of pelecypods and some illustrations which give a good promise of discovery in the Pitkin of additional pelecypods, while those already collected need a professional description and more nearly complete illustration. Thus it seems very likely that future work on our late Mississippian pelecypods will emend the present conclusion about the strong Pennsylvanian affinity of the Redoak Hollow pelecypods to that of more nearly balanced affinity with both earlier and later American forms.

PELECYPODA

Genus SOLEN Linnaeus

Solen LINNAEUS, 1758, Systema naturae, 10th ed., p. 672; SCHUMACHER, 1817, Essai d'un nouveau systeme des habitations des vers testacés, p. 42,124; WINCHELL, 1986, Proc. Acad. Nat. Sci. Philadelphia, p. 422; GARDNER, 1943, U. S. Geol. Survey Prof. Paper, 199-A, p. 108, pl. 23, fig. 40.

Clidophorus GEINITZ, 1866, Carb. and Dyas in Nebraska, p. 25, pl. II, fig. 7.

Solenopsis MEEK (in HAYDEN), 1872, Final Rep. U. S. Geol. Survey Nebraska, p. 223–224, pl. X, fig. 3; GIRTY, 1911, U. S. Geol. Survey, Bull. 439, p. 81, pl. XII, fig. 12.

Type species.—*Solen vagina* L. (Schumacher, 1917).

Representatives of the genus *Solen* have been recognized among late Paleozoic pelecypods on their general resemblance to scabbard-shaped shells, with subdued and anteriorly placed beak, gaping ends, and nearly smooth surface. However, since M'Coy introduced the name *Solenopsis* for some Paleozoic species previously referred to *Solen*, his name became gradually used in preference to *Solen* for some European and American late Paleozoic forms. The reason for this was the fact that their hinge remained unknown, and therefore their classification with *Solen* remained in doubt. Meek (1872) came near the correct understanding of the hinge of American shells when he remarked that

> All the specimens I have examined show an indentation just in advance of the beaks, somewhat like that left on internal casts of *Pleurophorous* by the internal ridge—Casts of the exterior, showing the finest lines of growth quite distinctly, indicate that the little indentation alluded to in front of the beaks must be impressed on the outside of the shell, though it doubtless also corresponds to an internal ridge.

EXPLANATION OF PLATE 89

FIG. *1–5*—*Solen* (*Solenomorpha?*) *gardneri*, n. sp. *1,2*, External and internal molds of right valve (holotype), ×2; *3*, internal mold of another right valve, ×2; *4*, detail of outer mold of left valve, ×10; *5*, detail of outer mold of right valve, ×20.

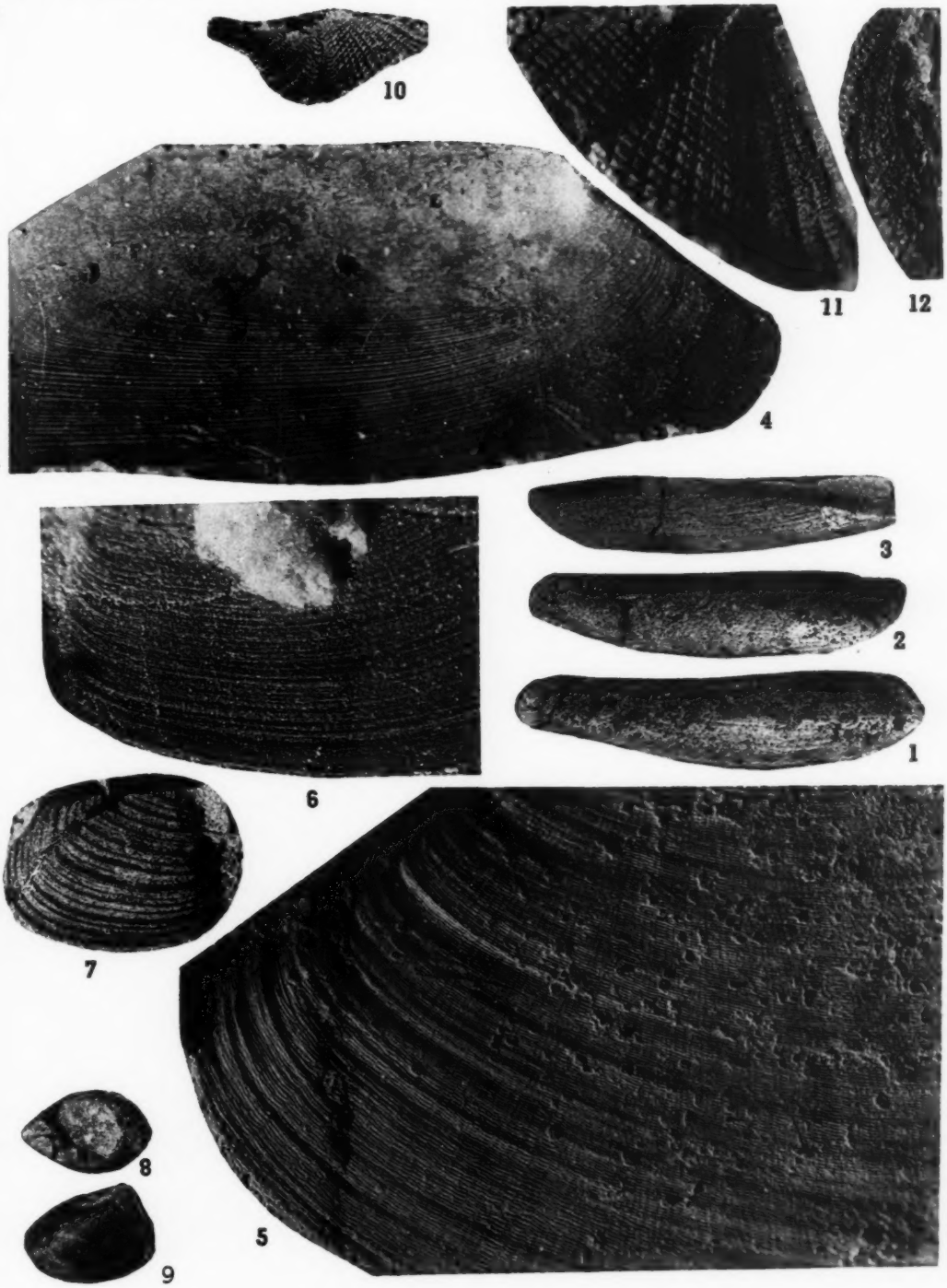
6—*Solen* (*Solenomorpha?*) cf. *S.* (*S.*) *solenoides* (Geinitz). From Weston shale, between Leavenworth and Soldier's Home, Kansas, ×10.

7—*Edmondia* cf. *E. senilis* (Phillips). External mold of left valve, ×2.

8,9—*Nucula* (*Nuculopsis*) *subventricosa*, n. sp. Top view and lateral view of internal mold of shell, ×1.

10—*Conocardium sayrei*, n. sp. External mold of right valve (holotype), ×10.

11,12—*Conocardium* sp. *A*.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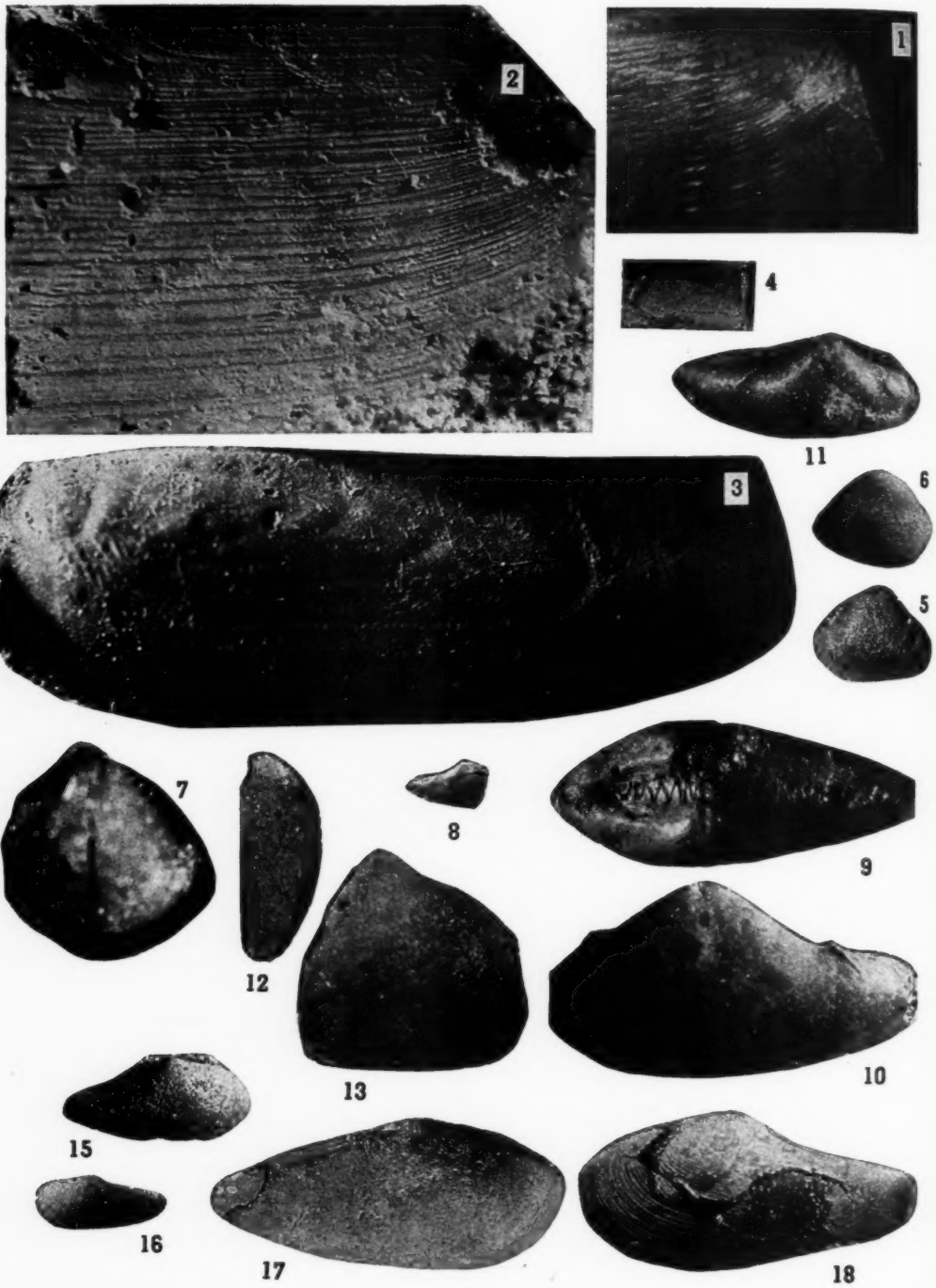
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Obviously, this reference to "ridge" is intended for what is usually termed tooth, which in *Solen* is located exactly at the same place, in front of the beak.

The fossil material from the Redoak Hollow here referred to *Solen gardneri*, n. sp., fully confirms this deduction by Meek, as it discloses for the first time the exact nature of the hinge and teeth of these late Paleozoic shells. Thanks to the excellent photograph of the interior of *Solen viridis* Say from Smith's Island, Virginia by Miss Gardner (1944) it is possible to compare the interior of this recent species with that of the shell from the Redoak Hollow, and it seems that in view of the similarity of their hinge structure it is appropriate to place this late Paleozoic shell in the genus *Solen*. Also, it seems reasonable to place in this genus the previously established American species *Solen scalpriformis* Winchell from the Mississippian of Michigan and *Solen solenoids* (Geinitz) from the middle Pennsylvanian of Nebraska. Furthermore, it seems that the European form for which M'Coy introduced the genus Solenopsis is also referable to *Solen*. On the other hand, "*Solenopsis nitida*" (Girty, 1910, 1910-A, p. 81, pl. XII, fig. 12) can not be placed with certainty in *Solen* because of insufficiently illustrated valve.

The material from the Redoak Hollow is surprisingly prolific and well preserved. So rarely has the genus been encountered in America before that in spite of the fact that Winchell repeatedly described (though never illustrated) a single species from the Mississippian of Michigan, and Geinitz and Meek subsequently described another species from the upper Pennsylvanian at Nebraska City, Nebraska, Girty described only one doubtful form, as just discussed, from the Mississippian of Arkansas, and did not record *Solen* or "*Solenopsis*" at all, either from the Mississippian or Pennsylvanian of Missouri and Oklahoma. Likewise, Beede & Rogers, who describe and list 192 species of invertebrates in the Pennsylvanian of Missouri and Oklahoma. Likewise, Beede & Rogers, who describe and list 192 species of invertebrates in the Pennsylvanian of Kansas, did not find a single representative of *Solen* or *Solenomorpha* (=*Solenopsis*) in this state. It has not been listed among the known invertebrates of the Mississippian or Pennsylvanian of Illinois, and is unknown in the Pitkin and its equivalents in Arkansas, Oklahoma, and Arizona.

The fragility of this thin and much elongated shell obviously can not account entirely for its rarity, because in the Redoak Hollow, where many other shells are found broken, most of the recovered individuals of *Solen* are not broken at all and preserve intact even their delicate sharp edges. Hence it seems that the fossil genus is rare not

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EXPLANATION OF PLATE 90

FIG. *1*—*Solen* (*Enis*) *viridis* Say. Anterior part of right valve, showing sculptural radial "ripples." Gulf of Mexico, off Florida Coast, ×10. Univ. of Nebraska State Museum Collection.

2,3—*Solen* (*Prothyris*) *soleniformis*, n. sp. *2*, Anterior part of external mold of left valve (holotype), showing sculptural radial ripples, ×10; and *3*, internal mold of left valve (holotype); showing antero-ventral notch typical of the subgenus, ×10.

4—*Solen* (?) cf. *nitida* (Girty). Internal mold of left valve, ×2.

5,6—*Nucula* (*Nuculopsis*) *subventricosa*, n. sp. Internal and external molds of left valve (holotype), ×1 (locality No. 2).

7—*Nucula anodontoides* subsp. *minuta*, n. subsp. Internal mold of left valve (holotype), ×10.

8–10—*Phestia inflata* (Girty). *8*, Internal mold of right valve, ×2; and *9,10*, top view and lateral view of an inner mold of shell, showing dentition, muscle scars, and a faint internal umbonal ridge (expressed as depression in the mold), ×10.

11—*Polidevcia* cf. *P. vaseyana* (McChesney). Internal mold of right valve, showing dentition and muscle scars, and a faint internal umbonal ridge (expressed as depression in the mold), ×10.

12,13—*Edmondia* (?) sp. Profile and lateral view of internal mold of left valve, ×2.

15–18—*Yoldia* (*Orthoyoldia*) *glabra* Beede & Rogers. *15*, Internal mold of adult right valve, ×1; *16*, internal mold of juvenile left valve, ×1; *17,18*, internal and external molds of most complete adult left valve, ×2.

because it is fragile but because the animal lived in rather restricted environments. Apparently the environments of the sea in Ardmore Basin at Redoak Hollow time must have been particularly suitable for the prolific occurrence of *Solen*.

Because living species of genus *Solen* have been differentiated into subgenera. *Ensis*, *Pharella*, *Cultellus*, and others, some of which have been recognized also in Tertiary material, it would seem proper to retain for the Carboniferous representatives of *Solen* M'Coy's name *Solenomorpha* by lowering it to subgeneric rank. However, in view of the fact that the hinge of M'Coy's genotype, *Solenopsis minor* M'Coy, is not definitely known (Hind, 1900, p. 414), American species which are here placed with *Solen* can only be placed questionably in the subgenus *Solenomorpha*.

Because of similarity of hinge and outer sculpture, including radial ripples or rays, *Prothyris* Meek is here considered also a subgenus of *Solen*, see discussion below.

SOLEN (SOLENOMORPHA?) GARDNERI, n. sp.
Pl. 89, fig. 1–5, Text-fig. 1–1,2

Seven separated scabbard-like valves, mostly right valves, have been recovered, nearly all complete, though some were accidentally broken when rock samples were collected in the field and in the course of preparation. Most valves are adult, measuring up to 35 mm. long and 8.5 mm. high with about 2 mm. convexity, the youngest valve is 28 mm. long, 6.5 mm. high, with about 1.5 mm. convexity. The beak in the adult is 3.5 mm. from the anterior edge. Very gently convex hinge starts about 3 mm. behind the beak and runs for about 25–26 mm. Posterior edge subtruncate. Ventral edge broadly rounded, sloping more rapidly posteriorly, so that the greatest height of the valve is about a third the total length from the anterior. Distinct umbonal ridge runs at an angle about 15° with the hinge, and reaches the postero-ventral angle about 3.5 mm. below the hinge. External sculpture is so gentle that the shell could be called smooth. However, its entire surface is covered with extremely fine and about equally spaced concentric lines of growth (about 40 per 1 mm. in the middle part) upon which are superposed concentric, gently angular plications, which vary from two to four or five times as wide as the regular lines of growth. Added to this concentric sculpture are radiating lines or "ripples" developed in the anterior part only. These "ripples" do not rise at all above the surface but are expressed by more distinct differentiation of the lines of growth along their path, which is from .05 to .08 mm. wide. The "ripples" are very densely spaced and run across the shell in the part anterior to to beak. Only a few reach to the beak itself. Generally they become shorter and scarcer posteriorly and disappear entirely at about $\frac{1}{4}$ to $\frac{1}{3}$ of length of shell behind the anterior.

The shell substance is comparatively thin, and because of this the concentric plications and even rays are reflected on the interior. However, the shell substance thickens perceptibly along the hinge for a distance of about $\frac{1}{3}$ the space between the hinge and the umbonal ridge. This linear thickening of the shell undoubtedly stiffens it perceptibly, and this fact apparently explains why it is found unbroken even when the valves become separated after death of the animal. The shell gaps distinctly at the posterior end and at the antero-dorsal end, just in front of the beak. In a single example of an immature valve (12 mm. long) there is a thin and narrow antero-dorsal wing differentiated from the valve by a straight and very narrow rib that runs from the beak in anteroventral direction at about 40° to the hinge line. This wing and rib are apparently broken in all collected adult valves.

The hinge behind the beak is augmented by a narrow plate which faces the similar plate on the opposite valve. These plates are longitudinally concave in much the same manner as seen in the photograph of *Solen viridis* Say by Gardner (1943, pl. 23, fig. 40). The plate is fused to the transverse tooth, a feature similar to that in *S. viridis*. In the latter species, however, the tooth is only a shade longer than the width of the plate but is three to four times as long as the width of the plate in *Solen gardneri*. According to the description of *S. viridis* by Say, 1922, quoted by Gardner, the species has "teeth one in each valve, each having a flattened vertical surface, which turns upon that of the opposite tooth,"—and this is

also the apparent relationship of the opposite teeth in *Solen gardneri*. Its platy teeth are oriented at an obtuse angle about 110° to the direction of the plate and are inclined at about 60° to the internal surface of the valve.

Discussion.—*Solen gardneri* is about 1½ times smaller than *Solen scalpriformis* Winchell from the Mississippian of Michigan and, in turn, is nearly twice as big as *Solen solenoides* (Geinitz) from the middle Pennsylvanian of Nebraska. These species are imperfectly known and have not been adequately illustrated, though there is little doubt that they are closely related to *Solen gardneri* and apparently belong to a single phyletic lineage. If so, the evolution of this lineage is from smaller to larger forms.

SOLEN (?) cf. S. NITIDA (Girty)
Pl. 90, fig. 4

A single left valve, as represented by outer and inner molds of its anterior half, differs from all other collected valves of the genus in a proportionally much smaller tooth, looks more nearly like prolongation of the hinge-plate, the latter bending in a crescent fashion under the beak, and wedging out rapidly below it. Another feature of the valve is the insignificant development of radial lines or rays which cover the anterior parts of the valve for a distance not more than 3.5 mm. or less than ⅛ of the total length of the shell. Judging by the outline of the growth lines, the shell reached about 18–19 mm. in length, while its height is 6.5 mm. Its ratio of height to length (or width) is about 1:3. The ratio of *S. gardneri* is 1:4. In the proportion of height to width the form is very near *Solen* (?) *nitida* (Girty) from the Moorefield shale of Arkansas and is only slightly smaller than the latter whose dimensions are: length 24.5 mm., height 8.5 mm.

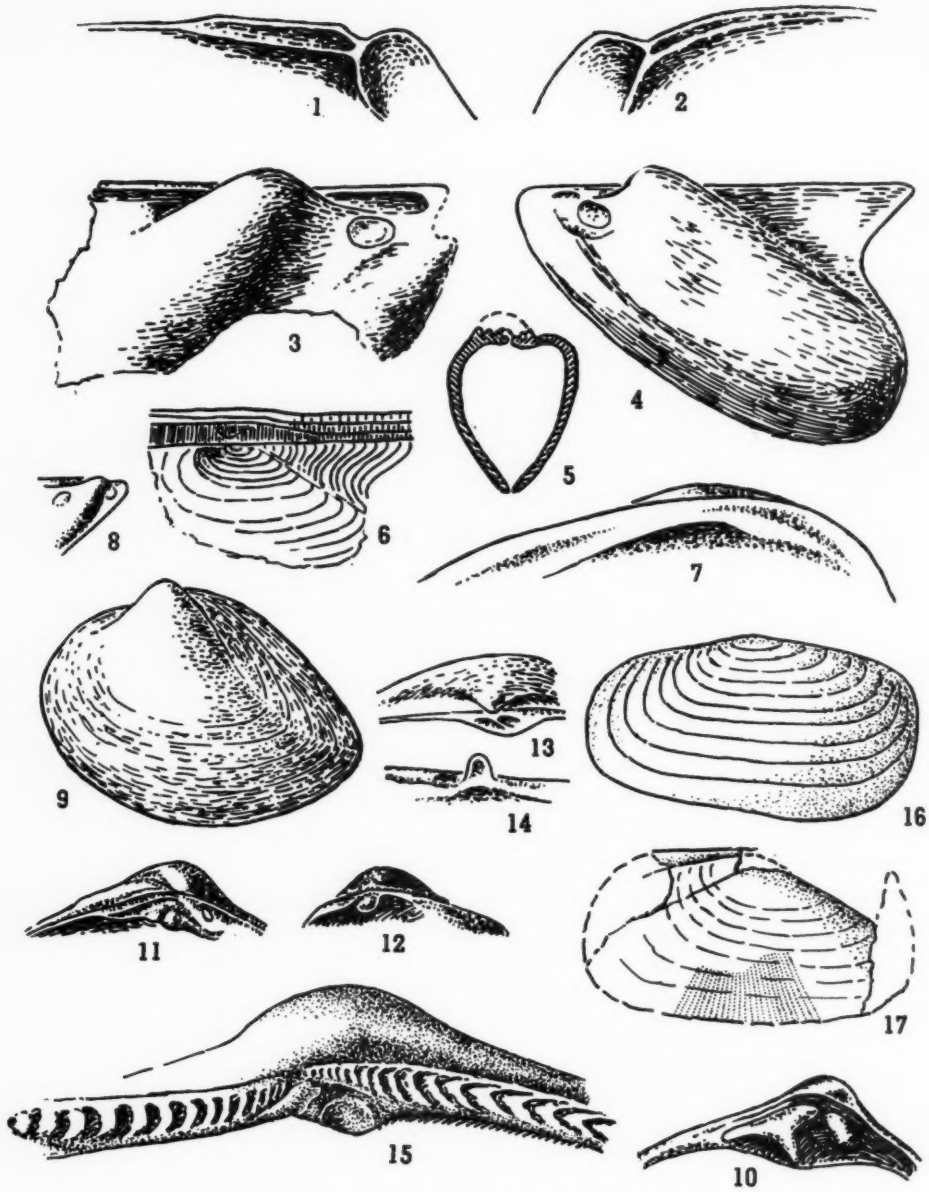
Subgenus PROTHYRIS Meek

Prothyris MEEK, 1869, Proc. Acad. Nat. Sci. Philadelphia, p. 172; ——, 1871, Amer. Jour. Conchology, vol. 7, p. 5, pl. 1, fig. 3; —— (In HAYDEN), 1872, Final Rep. U. S. Geol. Survey of Nebraska, pt. 2, Paleontology, p. 223, pl. X, fig. 9a,9b; WINCHELL (In MEEK), 1875, Pal. Contr.: Ohio, vol. 2, p. 305; DALL (In ZITTEL), 1913, Text Book of Paleontology, 2nd English Edit., p. 438; PRICE, 1916, West Virginia Geol. Survey, Riley County Rept., p. 708–710; MORNINGSTAR, 1922, Ohio Geol. Survey, 4th Ser., Bull. 25, p. 195–196.

This rare but well defined subgenus has been found through the Mississippian and all or nearly all of the Pennsylvanian in America, and at the base of Millstone Grit in Scotland (Hind, 1908). It is characterized by an elongated shell with subparallel dorsal and ventral margins, an indistinct anteriorly placed beak, and, particularly, by a deep antero-ventral notch that elevates the anterior edge about half way above the ventral margin. The type species, *Prothyris elegans* Meek, has been discovered in the uppermost division (Wabaunsee) of the upper Pennsylvanian exposed at Nebraska City, Nebraska, the highest known position in the stratigraphic range of the genus.

The new material from the Redoak Hollow adds valuable information on the structure of this genus. Its outer surface is sculptured much like the shell of *Solen gardneri*, the new species here described. It is covered completely by very fine concentric, more or less regularly spaced lines of growth, over which are superposed slightly raised angular plications, which vary in width from two to five times the width of growth lines. Besides, there are radial "ripples" in the anterior, which do not rise upon the surface of the shell but are made visible by sharper differentiation of the lines of growth within the narrow "ripple" which are about .1 to .2 mm. wide. These "ripples" are spaced about their own width apart in the extreme anterior but in the middle part of the shell, where only five such "ripples" can be counted, they are separated from each other by distances many times as large as their width.

The umbonal ridge is a gently angular bend that divides the valve diagonally into two subequal halves. No "ripples" have been noticed on the half of the valve above this ridge, where also both the concentric plications and the lines of growth are fainter than in the rest of the shell. The umbonal ridge is indicated to be sharper on the internal than on the external surface of the shell. All these characteristic details are much like *Solen gardneri*, and this seems to indicate a close relationship of *Prothyris* to *Solen*. The hinge in *Prothyris* is indeed



EXPLANATION OF TEXT-FIGURE *1*

1,2—Solen (*Solenomorpha*?) *gardneri*, n. sp. Hinge apparatus in the anterior of left and right valves, ×10.

3–6—Leptodesma (*Springeria*) *matheri*, n. subgen., n. sp. Internal molds of left and right valves, ×5; restored cross-section of shell, ×2; and details of umbonal area of right valve, ×10.

7—Edmondia splendens, n. sp. Hinge of left valve, ×3.

8—Pteronites cf. *P. angustatus* M'Coy. Internal mold of umbonal area, ×10.

9,10—Schizodus chesterensis Meek & Worthen. Squeeze from external mold of left valve, ×1½; and squeeze of the hinge of the same made from internal mold, ×2.

simpler than in *Solen*, but it is as straight as in the latter genus and has a faintly indicated crescent-like elevation anterior to the beak, which corresponds in position to the combined hinge plate and transverse tooth of *Solen gardneri*. Thus the poorly developed dental apparatus of *Prothyris* seems to exemplify the ancestral feature from which the more advanced apparatus of *Solen* evolved. In view of all these facts and considerations, *Prothyris* Meek is here considered to be a subgenus of *Solen* on a par with its numerous extant subgenera.

A very faint and densely spaced radial striation covers the whole inner surface of the valve, and because of this seems to be not a reflection of the radiating ripples of the outer surface but rather of radiating structure of the inner layer of the shell substance. Similar explanation has been offered by Hind for the "obscure radiating lines" observed on the inner molds of some species of *Sedgwickia* and *Edmondia* from the lower Carboniferous of British Isles (Hind, 1899, pl. XXVII, fig. 5–8; pl. XXX, fig. 3; pl. XXXIV, fig. 6).

SOLEN (PROTHYRIS) SOLENIFORMIS, n. sp.
Pl. 90, fig. 2,3

Two left valves of this species have been recovered, one represented by both external and internal molds, and the other only by an internal mold. Details of the external sculpture and of the faint dental apparatus of this species are described above, as they are considered of generic significance. Among specific characters of *Prothyris soleniformis* may be indicated the comparatively low position of the antero-ventral notch and the dimensions of the valve. The more nearly complete valve, which is the type of the species, is 12 mm. long (or wide) and 4 mm. high, and its convexity is about 1 mm. The posterior margin is truncated at an obtuse angle of about 115° to the hinge line, and is gently convex. The ventral margin (and also probably dorsal margin) is gently convex. The broken beak is apparently inconspicuous, does not rise above the dorsal edge, and is located at a distance about 2.5 mm. from the anterior edge.

Discussion.—*Prothyris soleniformis*, n. sp., differs from the stratigraphically younger *P. elegans* by being proportionally shorter: only three times as long as high, while the latter is 3½ times as long as high. It is also less than half the size of the largest specimens of *P. elegans*, though Morningstar (1922, p. 196) gives about the same dimensions as in our form to her "most perfect" of the two specimens from the Pottsville of Ohio, which however has the same proportion of length to height as in the other examples of *P. elegans*. The new species has also somewhat greater convexity than that in the latter form. However, perhaps the most important characteristic that sets the new species aside from those previously known is the development in it of an angular umbonal ridge, and possibly also the development of the faint radiating costae.

The stratigraphically older species *Prothyris meeki* Winchell, from the Waverly group of Ohio (In Meek, 1875, p. 305, pl. 15, fig. 2) and the Kinderhook of Ohio (Herrick, 1895, pl. 15, fig. 2), differs from both *P. soleniformis* and *P. elegans* by greater convexity of the valves, less sharply defined anteroventral notch, and a more sloping postero-dorsal margin, that gives the shell more nearly rhombic outline.

The lower Pennsylvanian (Kanawha) species *Prothyris carinata* (Price, 1916, p. 708–710, pl. XXX, fig. 14–16) differs from *Solen* (*Prothyris*) *soleniformis* in being not only proportionally more transverse, but also by its pronounced angular carina on account of which it received its name. Simi-

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11—*Schizodus harii* Miller, from Missourian Series at Kansas City, Kansas. Hinge of left valve, copied from Hind, 1898, ×1.
12—*Schizodus* cf. *S. batesvillensis* Weller, from the basal Millstone Grit of Scotland. Hinge of right valve, Copied from Hind, 1908, ×2, who described it as *S. wheeleri* (Swallow).
13—*Sedgwickia rugosus*, n. sp. Squeeze of umbonal part of internal mold of right valve, view from above to show the hinge, ×2.
14—*Tellinomorpha schencki*, n. sp. Squeeze of umbonal part of internal mold of right valve, view from below to show the hinge, ×2.
15—*Yoldia* (*Orthoyoldia*) *glabra* Beede & Rogers. Hinge of right valve, ×5.
16,17—*Sanguinolites* sp. D. Internal and external molds, ×5.

larly to *P. elegans* Meek, Price's species has a high anterior notch which segregates "a wedge-shaped lobe equal in height to one-half of the shell" that is much like that in *P. elegans* and unlike that in *S. (P.) soleniformis.*

Genus EDMONDIA de Konick

Edmondia DE KONINCK, 1843, Desc. des. Anim. foss., p. 66; HIND, 1899, Paleontographical Soc., vol. LIII, p. 286–291; DALL (In ZITTEL), 1900, Text Book of Paleont., 1st English Edit., p. 362; GIRTY, 1915, U. S. Geol. Survey, Bull. 544, p. 105–106.

Type species.—Isocardia unioniformis Phillips, 1836.

Girty's analysis of the history of the genus (1915, p. 105–106) discloses some uncertainties in the original description by de Koninck. This concerns the remark by the latter on "lunulate" anterior, which could have meant rather merely anterior gap, but even this was not correct, as Girty concludes, when taking into account our present knowledge of the material on which he based it. Another structure which Hind observes in the shells from the British Isles, but which Girty finds apparently lacking in the American species of *Edmondia*, is "an internal ossicle, elongate, flattened, which was directed outwards and downwards into the cavity of the umbo" (1899, p. 287).

One perfectly preserved mold of a left valve from the Redoak Hollow shows not only all essential characters of the genus *Edmondia*, but also seems to throw additional light on the structure which Hind described as an "ossicle" in the examples of the Old World form, but which Girty was not able to observe in the American representatives of the genus. He cautiously states, however, that the internal posterior ossicle would be naturally difficult of observation and I may have overlooked it (Girty, 1915, p. 105). Because the discussed left valve from the Redoak Hollow is represented by perfectly preserved external and internal molds, it is easy to detect in its internal mold a platy structure directed posteroventrally from the beak, and at a very sharp angle to the dorsal edge. This ossicle is similar to that illustrated on some of Hind's sketches of the internal cast (1899, pl. XXVII, fig. 16a,b; and pl. XXXI, fig. 4a).

Hind subdivides the genus *Edmondia* "into two well-marked groups: (a) those with fine regular concentric lines of growth, and (b) those with well marked concentric ridges and sulci. *E. uniformis* may be regarded as the type of the former, *E. sulcata* as characteristic of the latter . . . intermediate forms exist, *e.g. E. rudis*, which connects the two groups" (1899, p. 290). After the study of the previously unavailable type of *Edmondia senilis* (Phillips), Hind concluded that *E. rudis* M'Coy is its junior synonym (1904, p. 151). B. I. Chernyshev divides *Edmondia* into *Edmondia* in restricted sense, and *Edmondiella* (Chernyshev, 1950, p. 74) with *Edmondia (Sanguinolaria) sulcata* (Phillips) as type species. Judging by Chernyshev's placement in restricted *Edmondia* of his new species *E. raisae*, which he compares with *E. rudis*, the latter belongs also in *Edmondia*, and here belong also the two described forms from the Redoak Hollow.

EDMONDIA cf. E. SENILIS (Phillips)
Pl. 89, fig. 7

Corbula (?) senilis PHILLIPS, 1836, Geol. Yorkshire, pl. 2, p. 209; pl. 5, fig. 1.

A single internal mold, with incomplete posterior is only a fraction smaller than the smallest of the "three examples, dwarfed in size" of "*Edmondia rudis* M'Coy" illustrated by Hind (1899, sketches pl. XXVIII, fig. 12–14). Apparently Hind did not consider these three examples the young of the specie but rather truly dwarfed seemingly because of the environments unfavorable to their full growth; they all came from the Pennystone Ironstone Coal-Measures, Coakbrookdale of England.

The single specimen is right valve 16 mm. long, 13.5 mm. high, beak at a distance of $\frac{1}{4}$ of the length from the anterior edge, and convexity about 5.5 mm. The outline of the shell is subquadrate, and the surface marked by coarse concentric sculpture, but becomes nearly smooth at the anterior edge (posterior edge is broken off). A strong ligamental groove starts slightly in front of the beak and continues under it toward the posterior for an unknown distance.

While the general shape and size are very much like those in the dwarfed forms of *E. rudis* illustrated by Hind, the form from the

Redoak Hollow has a proportionally smaller convexity. Also, its internal surface, as reflected by the internal mold, is only slightly less coarse than the sculpture of the external surface, while the internal surface in *E. rudis* from the British Isles "shows obscure concentric grooves and rounded ridges, but is on the whole smooth" (Hind, 1899, p. 303). However, it seems possible that in the Ardmore Basin the interior layer of the conch in *E.* cf. *rudis* could have been dissolved quickly after the death of the animal, and only its outer layer left outer and inner impressions in the sedimentary matrix, the sculpture in both being coarse.

Edmondia gibbosa M'Coy has been recognized in the Pennsylvanian of America (Geintz, 1866, p. 16, pl. 1, fig. 23, 24, as *Astarte gibbosa;* Girty, 1903, p. 447, pl. 9, fig. 7–9; 1915, p. 107–108, pl. XIV, fig. 12; Butts, 1926, pl. 66, fig. 14, also listed by Price, 1916, p. 711 in Kanawha group of West Virginia) but these shells are almost twice as large as *E.* cf. *senilis* from the Redoak Hollow, though otherwise quite similar to it. Hence the form from the Redoak Hollow provides a link between the dwarfed Mississippian stock of *E. senilis* and the Pennsylvanian "*E. gibbosa*" of America.

EDMONDIA SPLENDENS, n. sp.
Pl. 91, fig. 3, Text-fig. 1–7

Parallelodon haimeanus HIND, 1897, Palaeont. Soc., vol. 51, p. 163–165; pl. XI, fig. 30,31.

The single specimen on which the following description is based consists of well preserved external and internal molds of a left valve, which faithfully reflect the details of its structure, though the matrix is fine-grained sandstone.

The valve is almost perfectly oval in outline, with only slight flattening in the middle part of the dorsal edge directly behind the beak. The beak is very slightly raised above this line and located about ¼ of the total length of valve from its anterior edge. Length of valve 24 mm., height 14 mm., and convexity 5 mm. The surface is covered by moderately prominent concentric lines of growth of somewhat variable strength and spacing. They are slightly more conspicuous in the dorso-anterior and posterior parts of the valve and almost fade out in the umbonal part. There is an almost imperceptible umbonal ridge that starts near the umbo and extends to about the middle of the posterior edge. A somewhat similar faint ridge is located very near the anterior edge.

The well preserved interior mold permits observation not only of the broad, incurved beak, but also of a posteriorly directed narrow plate or "ossicle" which starts from near the beak. A similar but much shorter place can be detected anterior to the umbonal area. The internal mold of the valve shows faint concentric lines of growth, which seems to indicate thinness of the conch.

Discussion.—Among the American species, *Edmondia splendens* is perhaps nearest to *E. ovata* Meek & Worthen (1874, p. 580; 1878, pl. 26, fig. 13) from the Pennsylvanian but differs from the latter by slightly more elongated shell, greater frontal position of the beak, and the presence of the gentle posterior and anterior umbonal ridges. Meek's sketches of *Edmondia reflexa* from the Pennsylvanian of Nebraska make it look more similar to *E. splendens* than does *E. ovata*, but Meek & Worthen's note in the inaccuracy of the sketch (Meek & Worthen, 1873, explanation to pl. IV, fig. 7), and their description cast doubt that this similarity is more than coincidence. Particularly important seems the difference in the proportion of length to width of the shell, which is about 2:1 in *E. reflexa*, its less forwardly placed beak, and coarser concentric sculpture. Most of the known Mississippian representatives of *Edmondia* are larger than and not as transverse as *Edmondia splendens*. *E. equilateralis* (Girty, 1915, p. 81, pl. VIII, fig. 9,9a) from the Batesville sandstone of Arkansas is small and has the same oval outline, but its dorsal edge is straight, and its beak located about ¼ of its length from the anterior edge. *E. fountainensis* (Weller, 1916, p. 247, pl. 17) from the Ste. Genevieve of Illinois is probably identical with *E. equilateralis* Girty.

Hind describes as *Parallelodon haimeanus* (de Koninck) several British specimens (1897, p. 163–165; pl. XI, fig. 28–31; pl. XIII, fig. 8), of which at least two (pl. XI, fig. 30,30a,31) may be referred to the genus *Edmondia*. The detail of the hinge, straight dorsal edge, and truncated posterior made

the specimen illustrated on pl. XI, fig. 27,28 an acceptable *Parallelodon*, but the rest of the illustrated specimens, whose interior is unknown, could be referred to *Edmondia*, and one (pl. XI, fig. 30,30a) has the same oval shape, position of beak, and concentric sculpture as *E. splendens*.

Family NUCULIDAE d'Orbigny

Schenck's revision of Nuculidae (1934) includes important corrections to the morphology of *Nuculopsis* Girty (1911) and introduction of new specific name *N. girtyi* for its genotype previously known as *Nucula ventricosa* Hall (specific name preoccupied).

Genus NUCULA Lamarck

The fundamental organization of the shell and the taxodont dentition characteristic of *Nucula* evolved in Paleozoic. Girty (1911) advanced good cause for the differentiation of some Pennsylvanian nuculids in the genus *Nuculopsis;* Schenck modified Girty's characteristics (1934) and incorporated in *Nuculopsis* several Mississippian and Pennsylvanian species (1939); and Shimer and Shrock judicially lowered *Nuculopsis* to subgeneric rank (1944).

Subgenus NUCULOPSIS Girty

Nuculopsis GIRTY, 1911, Ann. New York Acad. Sci., vol. 21, p. 133; ——, 1915, U. S. Geol. Survey, Bull. 544, p. 115–120; WILLIAMS & BREGER, 1916, U. S. Geol. Survey Prof. Paper 89, p. 173; SCHENCK, 1934, Bull. Musee r. d'Hist. natur. Belgique, vol. 10, no. 20, p. 29–30; ——, 1939, Jour. Paleont., vol. 13, p. 23–26, 40.

Nucula (*Nuculopsis*) SHIMER & SHROCK, 1944, Index Fossils of North America, New York, p. 375.

Type species.—*Nucula girtyi* Schenck (*N. ventricosa* Hall).

Girty believed that *Nuculopsis* differs from extant *Nucula:*

> "primarily because, though the beaks point toward the short side of the shell, that side is not posterior but anterior. This fact is determined by the occurrence of a ligamental groove or area along the hinge margin on the long side of the shell. Though varying in distinctness, traces of this structure in nearly all the numerous specimens of [*N. ventricosa* from the Wewoka of Oklahoma] examined . . . a real and persistent character of the species and is hardly open to any other interpretation . . . . The existence of this structure, then which has no homologue in *Nucula*, and its almost definite importance in determining that the long side instead of the short side of the shell is posterior, constitutes the most important difference from that genus" (1915, p. 116; also 1911, p. 133).

Additional difference from *Nucula* is that the

> "continuous series of taxodont denticles [is] not apparently interrupted by a chondrophore. . . . A chondrophore is almost certainly present, but, unlike the structure of living shells [of *Nucula*], it seems to be situated within and below the row of cardinal teeth without extending to the beak and forming interruption to them. This can not, however, be positively asserted" (p. 117).

Schenck (1934) disagrees with Girty's main observation.

> "An examination of a number of Recent specimens of *Nucula* that have lunular areas like that of the type of *Nuculopsis* proves to my satisfaction that the ligament of the Paleozoic species was internal . . . . In view of the fact that *Nucula ventricosa* Hall agrees morphologically with Recent species of known orientation, there is no reason for believing that the short side of the shell is anterior in the case of *Nuculopsis*. Thus, the erection of the new genus when based upon such imperfect observations and assumptions was a gamble. The name, however, has value, since it is the earliest

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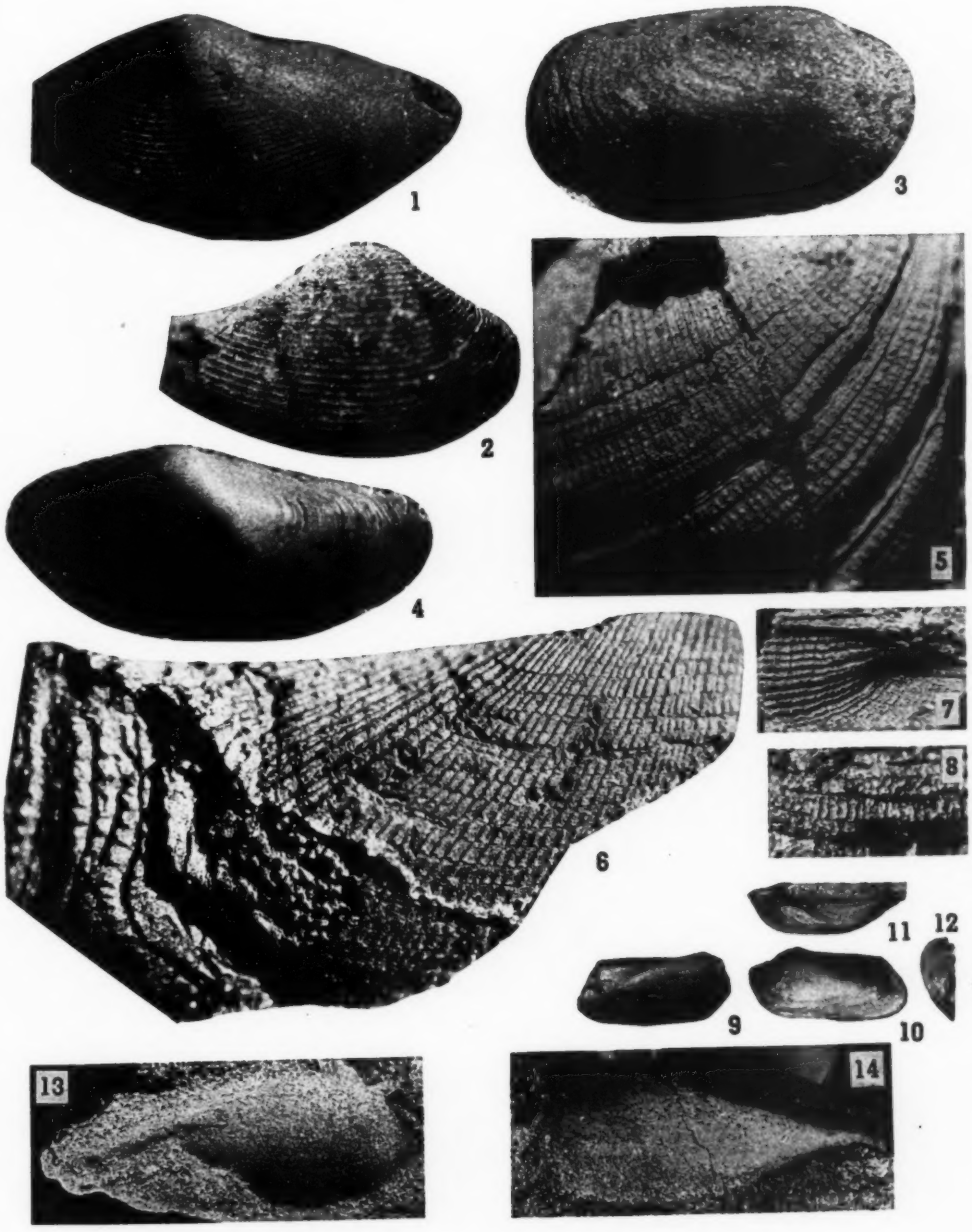
EXPLANATION OF PLATE 91

FIG. *1*—*Phestia inflata* (Girty, Morningstar). External mold of right valve; ×10.
2—*Phestia inflata* (Girty). External mold of left valve, ×10.
3—*Edmondia splendens*, n. sp. External mold of left valve, ×2.
4—*Polidevcia* cf. *P. vaseyana*. External mold of right valve, ×10.
5–12—*Parallelodon vokesi*, n. sp. *5–8*, Details of external sculpture of left valve (holotype), and of anterior posterior, and apical part and middle part of ventral edge, ×10; *9*, laterval view of inner mold or right valve, ×2; *9–12*, top, lateral, and anterior views of inner mold of left valve (holotype), ×2.
13,14—*Sanguinolites* (?) sp. *E.* External and internal molds, ×2.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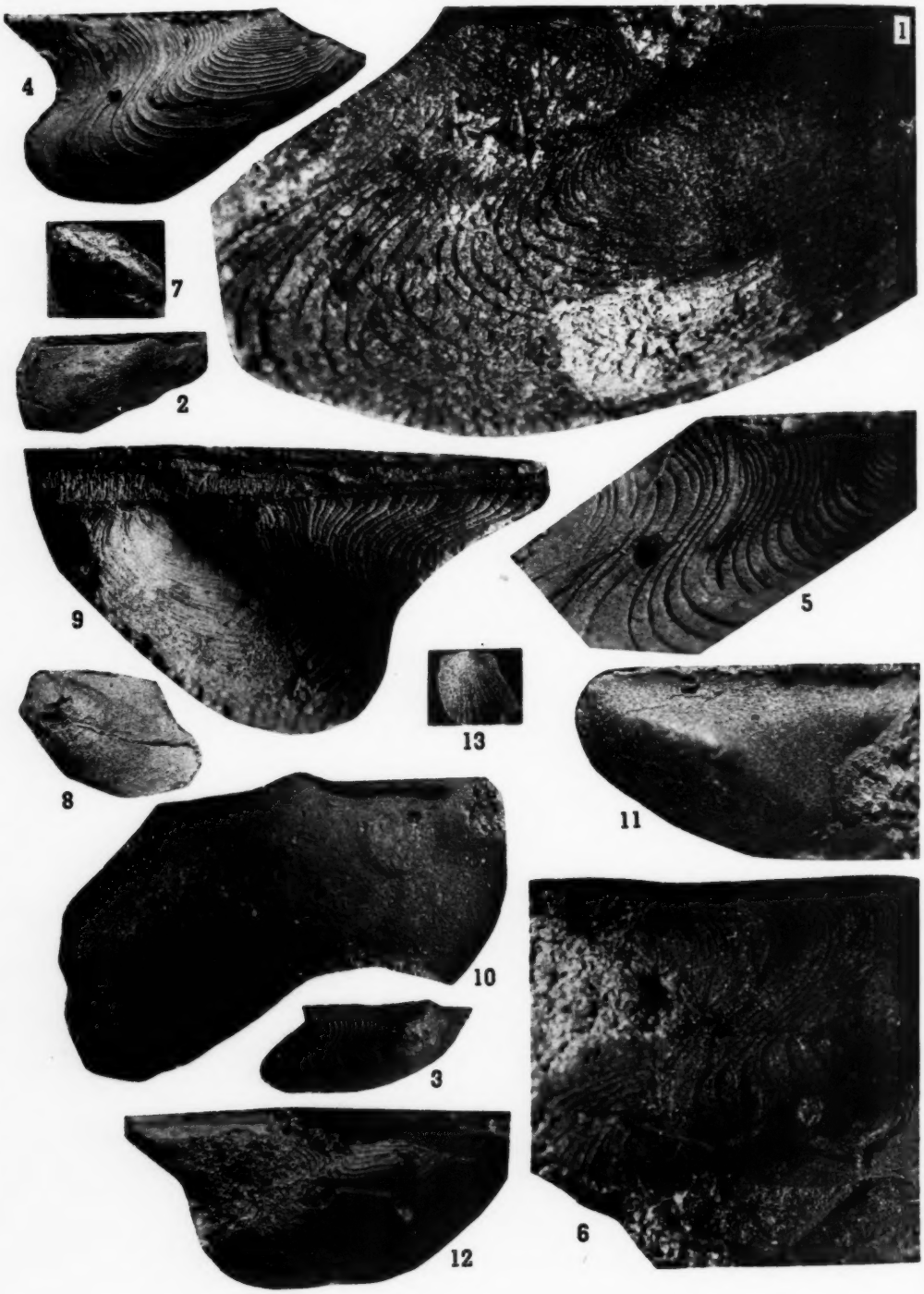
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applied to Paleozoic nuculids with a smooth ventral margin.

Nucula ventricosa Hall, 1858, is a homonym of *Nucula ventricosa* Hinds, 1843 (Proc. Zool. Soc., XI, p. 100). I propose, therefore, . . . *Nuculopsis girtyi* Schenck, new name for *Nucula ventricosa* Hall, 1858, not of Hinds, 1843, nor of Pchelintsev, 1927" (p. 29–30).

Schenck examined fossil *Nucula girtyi* (*ventricosa* Hall) from the Pennsylvanian of Iowa (his pl. 2, fig. 19) and from the Graham (upper Pennsylvanian) of Texas, but not the specimens from the Wewoka of Oklahoma examined and described by Girty. Ample material from the Wewoka collected by Allen Graffham and myself furnished several excellent examples of *N. girtyi* whose present examination confirms the contention by Girty that the chondrophore is fully under taxodont dentition. I also found a long, flat to very slightly concave, raceboat shaped groove, bordering the posterior dorsal edge of shell (shown in Girty's fig. 3,4c). This groove Girty apparently interpreted as a trace of ligamental attachment. However, the surface of the groove is not suggestive of such function, as the growth lines continue over it. The groove corresponds in this and other respects to the inner part of the escutcheon in *Nuculana attenuata* Fleming, as described and illustrated by Hind (1897, p. 196; pl. 15, fig. 2a) who speaks of the escutcheon "divided into two parts." Tschernyshev also describes and illustrates the same division of the escutcheon in *Polidevcia karagandensis* (1951, p. 26; pl. 2, fig. 22b). I suggest to term the inner part *inner escutcheon:* it is raceboat-like in outline, and divided from the outer escutcheon by a sharply defined curving ridge. Girty's observation that in *Nuculopsis* "the lunule and escutcheon are poorly defined" (1915, p. 116; 1911, p. 134) pertains to the lunule and to what would be now understood as outer escutcheon.

Schenck states that the presence of *chondrophore* "cannot be doubted" (1934, p. 29). Girty was somewhat uncertain not about its presence but whether it does or does not interrupt the row of the cardinal teeth under the beak, and the specimens available to him seemed to indicate that it does. Our material from the Wewoka indicates that while the chondrophore's outline is variable, it is always located below the row of teeth, being separated by them from the beak. Hence, as Girty suggested, the genus *Nuculopsis* differs from *Nucula* also in this respect, the chondrophore in the latter genus interrupting the row of teeth and extending to the beak.

Girty did not consider "the absence of denticulations along the [ventral] margins of the shell" an important character for differentiation of *Nuculopsis* from extant *Nucula*, because denticulation of venter "is absent in many of the modern species" (1915, p. 109). However, such species are now segregated in genus *Ennucula* (Iredale, 1913, p. 202); and Schenck suggested the use of Girty's *Nuculopsis* exactly because "it is the earliest one to be applied to Paleozoic nuculids with a smooth ventral margin, and, as far as I can tell, without definite concentric ribs, as in *Nuculana*" (1934, p. 30). But

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EXPLANATION OF PLATE 92

FIG. *1–8—Leptodesma* (*Springeria*) *matheri*, n. subgen., n. sp. *1*, External mold of nearly complete left valve encrusted by *Pycnopora ovatipora*, n. sp., ×10; *2*, internal mold of right valve with well preserved hinge and anterior muscle scar, ×2; *3*, external mold of complete left valve (holotype), ×2; *4*, external mold of nearly complete small left valve with well preserved details of external sculpture, ×10; *5*, detail of the same valve showing externally attached hollow tube of an unknown animal, ×20; *6*, external mold of a posterior of left valve with mold of *Heteronema priscum* subsp. *vinei*, n. subsp; *7,8*, nearly complete left valve, ×2, and external mold of right valve, ×2.

9–12—Leptodesma (*Springeria*) *stenzeli*, n. subgen., n. sp. *9*, External mold of right valve with well preserved sculpture of hinge, ×10; *10*, internal mold of right valve with the internal sculpture of hinge and circular anterior muscle scar, ×10; *11,12*, internal and external molds of left valve (holotype), with mold of *Heteronema prisca* subsp. *vinei* (?) attached to the external mold, ×10.

13—Paleolima inequicostata Mather. Inner mold of left valve, ×2.

in 1939 Schenck placed in *Nuculopsis* Pennsylvanian *N. croneisi*, and Mississippian *N. welleri* and *N. okawensis*, all with "concentric ribs" (p. 23–25; pl. 7, fig. 1–12).

In summary, the genus *Nuculopsis* differs from *Nucula, sensu stricto*, in having smooth ventral margin; and it differs from both *Nucula* and *Ennucula* by having the chondrophores not interrupting the taxodont dentition. Besides, the chondrophore in *Ennucula* is "notably oblique" (Iredale, 1931, p. 202; Schenck, 1934, p. 37).

Both nuculids from the Redoak Hollow can be placed in *Nuculopsis*.

NUCULA (NUCULOPSIS) SUBVENTRICOSA, n. sp.
Pl. 89, fig. 8,9; Pl. 90, fig. 5,6

The single specimen on which the new species is based consists of two valves tightly clamped together and with no gap anywhere along the ventral contact. The specimen is essentially an internal mold, but in its dorsal part and around the beaks the shell substance is preserved and adheres so tightly to the internal ferruginous mold that it was impossible to exfoliate it from the mold without destroying the shell, and probably also damaging the surface of the mold under it. Following are the internal dimensions of the shell, measured on the mold. Length: 20 mm.; height 14 mm.; thickness, from one valve to another, 11 mm. The shell substance is about 1 mm. thick at the beaks, the thickness diminishing very gradually toward the ventral edge, which seems to be about half as thick as the shell substance at the beak.

Discussion.—The new species resembles *Nucula* (*Nuculopsis*) *girtyi* (= *N. ventricosa*), but it has no inner escutcheon and this part of the shell instead of being grooved is rather inflated. Another difference from *N. girtyi* is the presence in the form from the Redoak Hollow of a low but nevertheless distinct ridge in the central part of the inner surface of each valve, that starts from near the beak and runs diagonally toward the middle of the ventral side of the shell. It is apparently homologous to the inner ridge in *Phestia* and *Polidevcia* but is less prominent than in the latter genera. *N. subventricosa* resembles *Phestia* in shape but differs by non-gaping shell.

NUCULA (NUCULOPSIS) ANODONTOIDES var. MINUTA n. var.
Pl. 90, fig. 7

Girty ventured to identify a species of *Nucula* from the Wewoka formation of Oklahoma with *N. anodontoides* Meek, which was described but not illustrated by Meek, and whose types he has not seen (it seems they are lost). Our form is much smaller than the adult specimens described either by Meek or by Girty, and could be considered a new species. However, in view of considerable variability of the shells included by Girty under the specific name *N. anodontoides?* it seems sufficient to consider it a new subspecies of the comprehensive species that includes both Meek's and Girty's shells. The distinction of the subspecies *minuta* is its small size: 3.5 mm. in width and 3 mm. in height. Girty's average specimen is slightly less than 14 mm. wide. Also, the ratio of height to width is slightly larger in *minuta* than in the specimen that is nearest to it in this respect (as illustrated by Girty, 1915, on pl. XIII, fig. 2a) and which is 12 mm. wide and 9 mm. high. The number of teeth in our form is about the same as *N. anodontoides:* 9 anterior and seven posterior (10 and 7 respectively counted in this species by Girty). Anterior muscle scar is about the same in both forms, but the posterior adductor in *minuta* is proportionally larger but flatter and is removed slightly farther away from posterior edge of the conch, as compared with the posterior scar illustrated on Girty's plate XIII, figure 2a.

Smooth ventral edge of shell and taxodont dentition uninterrupted by the chondrophore (see Girty, 1915; pl. XIII, fig. 5) place the species in the subgenus *Nuculopsis*.

Family LEDIDAE H. & A. Adams (1858)

Taxonomic priority of *Nuculana* (Link, 1807) over *Leda* (Schumacher, 1817) made the latter a junior synonym of the former, but left without change the family name Ledidae for the living and fossil marine pelecypods, which are broadly related to *Nucula*, but differ from it in distinctly lopsided (inequilateral) and wider than high shell. The late Paleozoic shells of the kind were customarily referred to *Leda* or *Nuculana*, though it was realized (Girty, 1911) that the Pennsylvanian forms so classified

differ from the Recent and Cenozoic *Nuculana* by having in each valve an internal ridge that starts below beak and divides the valve into diagnoally sub-equal halves by running toward the anterior, though never quite reaching it.

In 1951 B. I. Chernyshev (=Tschernyshew) introduced two new generic names, *Phestia* and *Polydevcia*, for two natural groups of late Paleozoic *Leda* as generally typified by the well known species *Nuculana inflata* (Girty) and *Nuculana attenuata* Fleming respectively. However, because Chernyshev designated as type species for each of his new genera his new Russian species, we are obliged to rely on his generic characteristics based on these legal types. Therefore, they are here translated and commented on.

Genus PHESTIA Chernyshev, 1951

Type species.—*Phestia inflatiformis* Chernyshev.

Age.—Upper middle Carboniferous (upper lower Pennsylvanian) C_2^3.

Locality.—Donetz basin, Southern European Russia (Chernyshev, 1951, p. 15–17; pl. 1, fig. 9–12).

"Shell *Leda*-like, small, elongate, posteriorly attenuate into rostrum, equivalve; beak opisthogyrate, somewhat elevated above hinge; no rounded depression. Sub-flat shield-like surface [escutcheon] delimited by lateral carina. An internal rib starts from near beak and curves as it extends toward antero-ventral edge, widening and disappearing when nearing pallial line. Large elliptical muscle scar near beak on anterior slope of this rib. Scar of anterior adductor small, rounded, strong; scar of posterior adductor of same size and strength, but elliptical. Pallial line without sinus.

Anterior and posterior parts of hinge meet at an angle under beak, where they are separated by an oblique resilifer. Teeth taxodont, those of posterior part nearly 1½ more numerous than in anterior part, and [become small when] lap over edge of resilifer; teeth of anterior part contact resilifer without change in size.

Ornamentation consists of numerous sharp concentric ridges.

Remarks: Weak sinus at postero-ventral edge in some species of the genus relates it to *Ledella* Verrill and Bush, 1897, but it differs in the reversal of the teeth ratio in anterior and posterior parts, and in the presence of internal rib. *Phaenodesmia* Bittner, 1907, is also similar, but has external ligament." (Chernyshev, 1951, .9)

The type species, *P. inflatiformis*, was originally described by Fedotov (1932) as *Leda* aff. *L. inflata*. Chernyshev places *L. inflata* Girty in *Phestia*, remarking that the type species differs from it only in being much less inflated and having posterior edge less inclined. He considers *Phestia snjatkovi* Chernyshev (1951, p. 12) still closer to *P. inflata*.

PHESTIA INFLATA (Girty)
Pl. 90, fig. 8–10;
Pl. 91, fig. 1

Leda inflata GIRTY, 1922, Ohio Geol. Survey, 4th Ser., Bull. 25, p. 205, pl. X, fig. 22–24.

The original form from the Morrow of Oklahoma was named and described by Girty in a manuscript, and the description is quoted by Miss Morningstar, who also illustrated Girty's type.

The single outer mold of a left valve has typical outline and concentric sculpture which allow the identification with Girty's type. The density of the sharp concentric striae is about 9 per 1 mm. in the mature central part of the valve. The posterior is attenuated and the shell is smooth along the whole length of the umbonal ridge which is situated near the posterior part of the dorsal border. The valve is about 6 mm. long and 3 mm. high.

The shell is nearer to *Phestia* (*Leda*) *inflata* (Girty) than *P.* (*L.*) *bellistriata* (Stevens), a very common Pennsylvanian species, but differs from *P. inflata* by smaller size, sharper attenuation of the posterior, and greater inflation of its central part, the features on which Girty differentiated it from *P.* (*L.*) *bellistriata*. Morningstar records occurrence of *Phestia* (*Leda*) *inflata* in the lowermost fossiliferous part of the Pottsville of Ohio, the Sharon iron ore bed. In the Lowellville limestone and still higher rocks of the middle Pottsville its place is taken by *Phestia* (*Leda*) *bellistriata*. According to Girty and Roundy (1923) *P.* (*L.*) *inflata* is found in the Otterville and possibly Jolliff (Tomlinson 1929, p. 75), while they identify *P.* (*L.*) *bellistriata* in the upper Deese. Mather questionably identified *P.* (*L.*) *bellistriata* in the Hale formation (1915, p. 212, pl. XVI, fig. 19), a valve which is near the original Stevens's shell in its dimen-

sions; but its sharply attenuated posterior is like that in *P.* (*L.*) *inflata*; hence in this respect it is a transitional form from the latter species to the typical *P.* (*L.*) *bellistriata* of post-Morrow time.

Genus POLIDEVCIA Chernyshev

Type species.—*Polidevcia karagandensis* Chernyshev, 1951.

Age.—Lower Carboniferous.

Locality.—Karaganda, Kazakhstan, southwestern Siberia.

"Shell equivalve, inequilateral, posterior twice as long as anterior or longer. Beaks opisthogyrate. Lunule delimited by narrow carina, lanceolate, covered with concentric ribs. Escutcheon wide, delimited by a blunt keel, and divided into two parts by another carina, which extends from beak to edge of valve, where it points upwards; anterior of escutcheon slightly concave.

Anterior and posterior parts of hinge meet under beak at an angle; teeth of anterior part extending to end of lunule, and teeth of posterior part extend to point of upward turn of valve's edge. *Chondrophore absent.* Teeth taxodont, sub-equal in number in anterior and posterior parts. Scars of both adductors weak. Pallial line without sinus. [Central] inner rib short, but clearly indicated. Scar of umbonal muscle large, located on inner rib near beak; two additional, smaller scars under it. Another, short inner rib at rear end of valve. Sculpture consists of sharp concentric ridges, which bend sharply when crossing carina which delimits escutcheon, and extend over it, frequently becoming fainter when crossing carina (Chernyshev, 1951, p. 25; my italics).

The italicized part, which reads "Chondrophore absent," is probably an error of observation or a typographic error. Careful scrutiny of Chernyshev's descriptions and illustrations of his species shows that he never observed any inner structure in the type species (*P. karagandensis*) or other species, and makes no clear statement of absence of chondrophore in a few species whose dentition he describes.

By placement in *Polidevcia* Fleming's *Nuculana attenuata* and Stevens' *N. bellistriata* he admits in his genus the forms which certainly do have chondrophore, and it seems inconceivable to think that he has not realized it. Both mentioned species may be safely placed in *Polidevcia* as they fit the generic diagnosis in all other respects.

The matter of the chondrophore was brought to the attention of Dr. Norman D. Newell who stated as follows:

"I am quite skeptical about the lack of resilifers in any of the late Paleozoic shells similar to *Nuculana*. Unfortunately the literature is filled with statements of this sort: specimens are said to lack certain characteristics, simply because the author did not have good material available for his examination.

POLIDEVCIA cf. P. VASEYANA
(McChesney)
Pl. 90, fig. 11;
Pl. 91, fig. 4

Nuculites vaseyana McCHESNEY, 1860, Desc. New Species Pal. Foss., p. 73. ——, 1865, Illustrations New Species Foss., pl. 7, fig. 4a–d.
Nuculana vaseyana McCHESNEY, 1868, Chicago Acad. Sci., Trans., vol. 1, p. 37, pl. 7, fig. 4a–d.
Leda vaseyana GIRTY, 1911, U. S. Geol. Survey, Bull. 439, p. 83–84; pl. XI, fig. 7.

Several nearly perfect to partly broken internal casts resemble *Polidevcia vaseyana* closely, differing from it externally in slightly smaller size and not as far anteriorly placed beak.

The shells from the Redoak Hollow are 5½ to 6 mm. long, and 3 to 3.5 mm. high. The beaks are placed a little more than ⅓ of the length from the anterior edge. Convexity of valves is 1 to 1.5 mm. The outline of the shell is widely rounded ventrally and subangular dorsally, the beak rising above the curving hinge line. A row of subequal strong teeth lines up the hinge, with a total of 19 or 20 on each valve, and about equally divided on each side from the beak. Both posterior and anterior adductor scars are distinctly depressed on the sides facing the beak. There is an umbonal elevation on the inner side of each valve, that runs from the beak in diagonal, postero-ventral direction, but this elevation is not strong and disappears about half way toward the ventral edge. The surface of the shell is covered with densely spaced sub-equal concentric fila.

The internal molds of the form from the Redoak Hollow resemble closely the internal mold from the Moorefield shale of Arkansas, which Girty identified with McChesney's species (Girty, 1911, p. 83–84, pl. XI, fig. 7). Indeed, Girty does not show or describe the dental apparatus and other details, but the general outline, small size (10 mm. long), position of the beak, and weakness of interior umbonal ridge are so similar to the same in the form from the Redoak Hollow that it may be at least provisionally identified with *Polidevcia vaseyana*

in broad understanding of this species. However, *P. vaseyana* has from twelve to sixteen teeth on each valve, as counted by McChesney, that is only ⅔ to ¾ the number of teeth in the shell from the Redoak Hollow, while Girty made no observation on teeth (or other details) for his not too well preserved material from the Moorefield. Perhaps the form from the Redoak Hollow could be differentiated as new variety of *Polidevcia vaseyana*, but our knowledge of this form and its variation is at the present too meager for an assured formulation of distinctions on which such taxonomic differentiation could be based.

The successor of *Polidevcia vaseyana* in the higher Pennsylvanian beds is apparently *Polidevcia bellistriata* Stevens, which is distinguished from McChesney's species by larger size, more pronounced inner ridge, and development of diminutive lamellar teeth in the part of the hinge opposite the beaks (Girty, 1915, pl. XIV, fig. 5,6, and 9). In the general outline the shell from the Redoak Hollow is undoubtedly closer to that of the Mississippian *P. vaseyana*, particularly as illustrated by Girty, than to *P. bellistriata* from the upper Morrow (Mather, 1915, p. 212–214, pl. XV, fig. 19) and higher Pennsylvanian horizons.

Genus YOLDIA Möller

The genus differs from others of the family Ledidae by laterally compressed conch whose slightly convex valves are thin, with inconspicuous sub-centrally located beaks. Shell gaps posteriorly and in some species also anteriorly. Pallial line with deep sinus in post-Paleozoic species.

Confusion in the taxonomy of *Yoldia* and its subgenera arose because the two species for which the genus was introduced were not illustrated, and species other than these were subsequently designated as types for the genus (Grant & Gale, 1931, p. 126–128). Woodring's designation of "*Nucula arctica* Möller not Gray" as a type species is valid, but supplies no information what Möller's species is like. Mossevitch investigated occurrence and variability of *Yoldia arctica* in the Arctic Sea. His illustrations of typical shells of this species are republished by Grant & Gale (1931, p. 1, fig. 10, 11) and considered acceptable examples of *Yoldia arctica* (Gray), as Möller cited this species for his genus *Yoldia*. Thus, "*Y. arctica*, *Nucula arctica* Gray" (1879, p. 19).

In view of the absence of authentic holotype for *Yoldia arctica*, the larger of the two specimens illustrated by Mossevitch and republished by Grant & Gale (1931, pl. 1, fig. 10) is here designated neotype for *Y. arctica*. The other, smaller specimen (pl. 1, fig. 11) is "The variation that Mossevitch recognizes even in the typical variety" (pl. 1, p. 880).

Taking all this into account the following is suggested:

(1) The genus *Yoldia* in restricted sense (or subgenus *Yoldia* of genus *Yoldia*), as determined by Mossevitch and accepted by Grant & Gale, has a sag in the center of hinge and an acuminate posterior caused by postero-ventral constrictuion.

(2) In view of this, Verrill & Bush's proposal to restrict the genus *Yoldia* "to the typical forms, such as *Limatula* (Say) (fig. 12), *sapotila* (Gld.) (fig. 16), *myalis* (Couth.) (1875, p. 55)" is invalid.

(3) *Orthoyoldia* Verrill & Bush, which "includes the Yoldias with a soleniform or elongate elliptical shape" as formulated by Grant & Gale (1925, p. 128) and accepted by Woodring (1925, p. 21) is a valid taxon, a section or subgenus of the genus *Yoldia*.

Hind (1897, p. 193) excluded from *Yoldia* all Paleozoic species referred to the genus by the previous authors. Girty (1915, p. 120–122,125–126) agrees with this exclusion but transfers some of the species placed by Hind (1897) in *Nuculana* to the genus *Anthraconeilo* Girty, and retains in *Yoldia* a single American species *Yoldia glabra* described by Beede & Rogers (1899, 1900) from the lower part of the Virgil Series in Kansas. Girty described this same species on excellent material from the Wewoka formation (upper Marmaton group, Des Moines Series) of Oklahoma and found that its interior (previously unknown) is not unequivocally *Yoldia*-like:

> "Some specimens show a very narrow, ill-defined area back of the beaks, suggesting an obscure escutcheon. The posterior edges of the shell are pinched together here so that they are in flat contact and have a vertical direction.
>
> "This configuration hardly suggests a ligamental area, a similar structure on the short

side of the beaks observable in some cases having more the appearance of ligamental groove. If such is their nature, however, the entire orientation of the shell is changed and the genus is very distinct from *Yoldia*" (1915, p. 126–127).

In the ample new collections of the species from the lower Virgil of Kansas, and the Wewoka, the Morrow, and the Redoak Hollow of Oklahoma I found no indication of the structure suggestive of ligamental groove, such as illustrated by Girty (1915, p. 13, fig. 12), probably rarely developed. The shape, sculpture, and taxodont dentition in species *glabra* are typical for *Yoldia* and particularly for subgenus *Orthoyoldia* Verrill & Bush, in which it may be placed, unless differentiated into a new extinct subgenus.

Complete comparison of *Yoldia/glabra* with *Y. arctica* is at the present handicapped by the apparent insufficiency of published information on the hinge and dentition of the latter.

YOLDIA (ORTHOYOLDIA) GLABRA
Beede & Rogers
Pl. 90, fig. 15–18

Yoldia glabra BEEDE & ROGERS, 1899, Kansas Univ. Quarterly, vol. 8, no. 3, p. 133, pl. 34, fig. 4a,4b; BEEDE, 1900, Kansas Univ. Geol. Survey, vol. 6, p. 153, pl. 21, fig. 4a,4b; GIRTY, 1915, U. S. Geol. Survey, Bull. 544, p. 126–127, pl. XIII, fig. 9–15.

Ample material from the Redoak Hollow with well preserved exterior and interior permits detailed comparison with the *Yoldia glabra* from the Wewoka described and illustrated by Girty in some detail (no interior was described by Beede & Rogers). The agreement between them is so close that their specific identity is undoubted.

The best preserved valve (Pl. 90, fig. 17, 18) is 25 mm. wide, 12 mm. high, with 2.75 mm. maximum convexity. Beak is small, slightly raised above hinge, only slightly closer to anterior than to posterior. Anterior end broadly rounded, posterior attenuated to nearly $\frac{2}{3}$ width (height) of the anterior, and less broadly rounded than the anterior. Shell gaping at the posterior and less at the anterior. Sculpture consists of subequal slightly convex concentric ribs, the sharp grooves between them steeper ventrally. Ribs increase in width from beak downward, reaching maximum about $\frac{2}{3}$ way to the venter, and then become narrower again. A barely perceptible broad constriction of the ventral border at a distance about $\frac{1}{3}$ total length of shell from the posterior is reflected in the concentric ribs. Posterior to the constriction the sculpture is crossed diagonally by a similar but less regular concentric sculpture of the posterior end.

Dentition is divided into anterior and posterior parts, nineteen to twenty teeth in the anterior eight of which above the chondrophore are much reduced in size. Less reduced are three or four of the seven to nine posterior teeth that lap over a "button" or "chondrophore tooth," which borders chondrophore posteriorly. Chondrophore subflat or slightly concave.

Anterior and posterior adductors are faintly indicated. Sharp internal plate oblique to hinge and posterior to beak is located under external depression suggestive of escutcheon.

Several specimens examined show but little variability in the shape, position of beak, and dentition.

Discussion.—*Yoldia* (?) *levistriata* Meek & Worthen (1860, p. 457; 1866, p. 282, pl. 20, fig. 7a,b) from Ste. Genevieve limestone of Illinois was not discussed by Hind (1897) or by Girty (1915). Its interior is unknown, and externally it is transitional between *Nuculana* and *Yoldia* in "slightly gaping" posteriorly (Meek & Worthen, 1866, p. 282). It could be a link between some early Mississippian *Polidevcia* and late Chester *Yoldia* (*Orthoyoldia*) *glabra*. It differs from *Y. glabra* in being time and a half shorter and two times thicker.

Genus PARALLELODON Meek

Macrodon LICETT, 1844, Murch. Geol. Chelt (not seen). Name preoccupied by MUELLER, 1842, for a genus of fishes.

Parallelodon MEEK & WORTHEN, 1866, Proc. Chicago Acad. Sci., p. 17; DE KONINCK, 1885, Ann. Mus. d'Hist. Nat. Belge, vol. XI, p. 140; HIND, 1897, Pal. Soc., vol. LI, p. 125–130; DALL (In ZITTEL), 1908, Text Book of Paleontology, 2nd English Edit., p. 441; GIRTY, 1908, U. S. Geol. Survey Prof. Paper 58, p. 422–425.

A comprehensive discussion of the morphology and history of the genus is given by Hind (1897), and a brief summary of same was published by Girty in 1908. Soon after

this date American paleontologists began to use the name *Parallelodon* instead of *Macrodon* for these late Paleozoic pelecypods (even in Meek's own papers, published since his suggestion of change of name, the generic name *Macrodon* and not *Parallelodon* is used).

As Girty (1908, p. 423) concludes,

> "Both because the term *Macrodon* was preoccupied, because *Macrodon* was based on a Mesozoic and *Parallelodon* on a Paleozoic type, and because they show certain differences in dentition, though these may be small, it seems to me highly advisable, especially in the case of Paleozoic species, to use the term *Parallelodon*."

The whole group of numerous pelecypods united by Hind under broadly understood *Parallelodon*, includes not only the rhomboidally-shaped reticulate-sculpture species, which one time were called *Macrodon* and to which the generic name *Parallelodon* is currently applied in America, but also species with oval outline and simple, concentric sculpture such as in *P. haimeanus*. Hind himself felt a necessity to subdivide the much too heterogenous group using their sculpture as the principal character for differentiation. He thus segregated it into Group A, "with transverse, widely separated, imbricating lamellae"; Group B, "with reticulate markings"; and Group C, possessing "surface smooth, with transverse, or with microscopic lines only" (Hind, 1897, p. 130). American species classified in *Parallelodon* belong entirely in Hind's group B.

Parallelodon is one of the most common among the pelecypods in the lower Carboniferous (Dinantian) of British Isles and western Europe, while it is comparatively rare in the Mississippian and Pennsylvanian of America. Hind classifies the Old World species into three groups of subgeneric rank but does not give names to these ranks and merely indicates them as groups A, B, and C. The basis for this division is primarily the character of sculpture of the shell, not their shape or hinge apparatus or inner structure, which are largely unknown. The largest is group B, with eleven species, and this group is characterized by a more or less equally strong development of both radical and concentric costae so that a cancellate pattern is produced.

The described new species, *Parallelodon vokesi*, belongs in this group, and particularly in a subgroup of species, as this can be further segregated, where this pattern is most typically developed and most evenly distributed over the surface of the shell. In this group and the subgroup belong also the following American species: *P. sangamonensis* Worthen and *P. cancellosus* Mather from the Pennsylvanian, and the Old World species *P. reticulatus* M'Coy, *P. cancellatus* Martin, *P. lacordaireanus* de Koninck, and *P. concinnus* M'Coy, all from the Dinantian (Mississippian).

PARALLELODON VOKESI, n. sp.
Pl. 91, fig. 5–12

(?)*Parallelodon concinnus* HIND, 1897, Pal. Soc., vol. LI, pl. XII, fig. 22.

Well preserved external and internal molds of the right and left valves have been found in a small rock fragment in such close proximity, and having their sizes so closely identical, that they must have come from the same shell.

The genus is known to be equivalve, and so indeed is the new species from the Red-oak Hollow. Fragments of isolated valves have been collected also and they indicate shells of about the same size as that of the above mentioned pair of the valves of the complete individual on which the following description is based.

The shell is 13 mm. long (or wide), 6.5 mm. high, and the convexity of each valve 3 mm. Hinge is straight, 11 mm. long, meeting the straight upper part of the posterior edge at 110°. Farther down this edge becomes slightly concave, and then curves around the postero-ventral corner. The ventral edge is parallel to the hinge, but is slightly and broadly concave in the middle. The anterior is broadly rounded, extending farthest out, and is a little below and about 0.5 mm. beyond the anterior end of the hinge. Beak directed forward, strongly incurved, broad and flattened parallel to the axis of incurvation, its tip located about 3.5 mm. from the anterior.

Surface strongly ornamented by numerous subequal radiating costae over all exterior of the shell, and so are the concentric lines of growth of three kinds: very numerous faint striae; more or less regularly

spaced (4 per 1 mm.) fila, which are almost as prominent as the radiating costae; and very strong but less regularly spaced lamellar elevations in the more mature and gerontic parts of the shell. The radiating costae are spaced somewhat denser than the regularly spaced fila, and average about 6 per 1 mm. in the mature part of shell. Their crossing with the latter produces a peculiar cancellate pattern, which may be described thus: the radiating costae (flat and as wide as or narrower than the depressions between them) are divided regularly by very narrow transverse grooves into radially elongated rectangles. The same kind of sculpture, only in a much larger scale, has been described and illustrated by Hind for *Parallelodon ornatissimus* de Koninck from the Lower Carboniferous of Europe. The radial costae are thinner and more crowded in the umbonal region and spread gradually apart ventrally, but a few additional costae are also added ventrad between them through intercalation.

Subangular ridge is developed from the umbo postero-ventrally, ending at the point where the concave edge of the posterior truncation changes to the convex curvature of the postero-ventral extension. Three radial costae located on this ridge are slightly more prominent and separated from each other by wider grooves than the neighboring costae on either side of the ridge. There are eleven ordinary ridges between the costae of the ridge and the hinge; only a few of the more prominent concentric filae and all of the coarse lamellar corrugation cross these postero-dorsal costae.

Sharply defined horizontal edge truncates both valves dorsally and produces what is known as horizontal "area." This linear area extends under the over-hanging incurved beaks and forms elongately triangular platform in front of them. This platform is only slightly longitudinally striated by a few lines of growth that extend here from the anterior of the shell. The hinge surface is perpendicular to the area and is provided with long longitudinal teeth posteriorly and several very short diagonal teeth anteriorly. Because of the partial breaking off of the anterior part of the hinge the exact number of its diagonal teeth cannot be ascertained. On the other hand the posterior dentition is fully preserved and shows its very gradual elevation and differentiation posteriorly. At the posterior end there are three to four horizontal teeth, each being finely transversely striate or serrate, all ending abruptly 1½ mm. before the end of the hinge.

A similar comparatively wide ligamental area that extends nearly the whole length of shell has been observed in *Parallelodon ornatissimus* de Koninck (Hind, 1897, p. 155, pl. XIII, fig. 3a); a narrow one in *P. tenuistriata* M'Coy (ibid, p. 151) and *P. fallax* de Koninck (ibid., p. 162, pl. XI, fig. 27b); a narrow concave area in *P. corrugatus* de Koninck (ibid., p. 144, pl. X, fig. 17); an area not extending the whole length of shell in *P. reticulatus* M'Coy and *P. verneuillianus* de Koninck, all but the last one in group B (with cancellate ornamentation).

There is not a trace of umbonal depression or concavity, so common in the genus, and yet a gentle concavity is developed in the middle of the ventral edge of a wholly mature shell, where usually the umbonal concavity (or byssal sulcus) attains its maximum width. On the other hand, a peculiar rounded ridge is observed on the inner side of each valve, starting from the anterior

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EXPLANATION OF PLATE 93

FIG. *1,2*—*Pteronites* cf. *angustatus* M'Coy. Internal mold of left valve (×2) and detail of its anterior (×10).

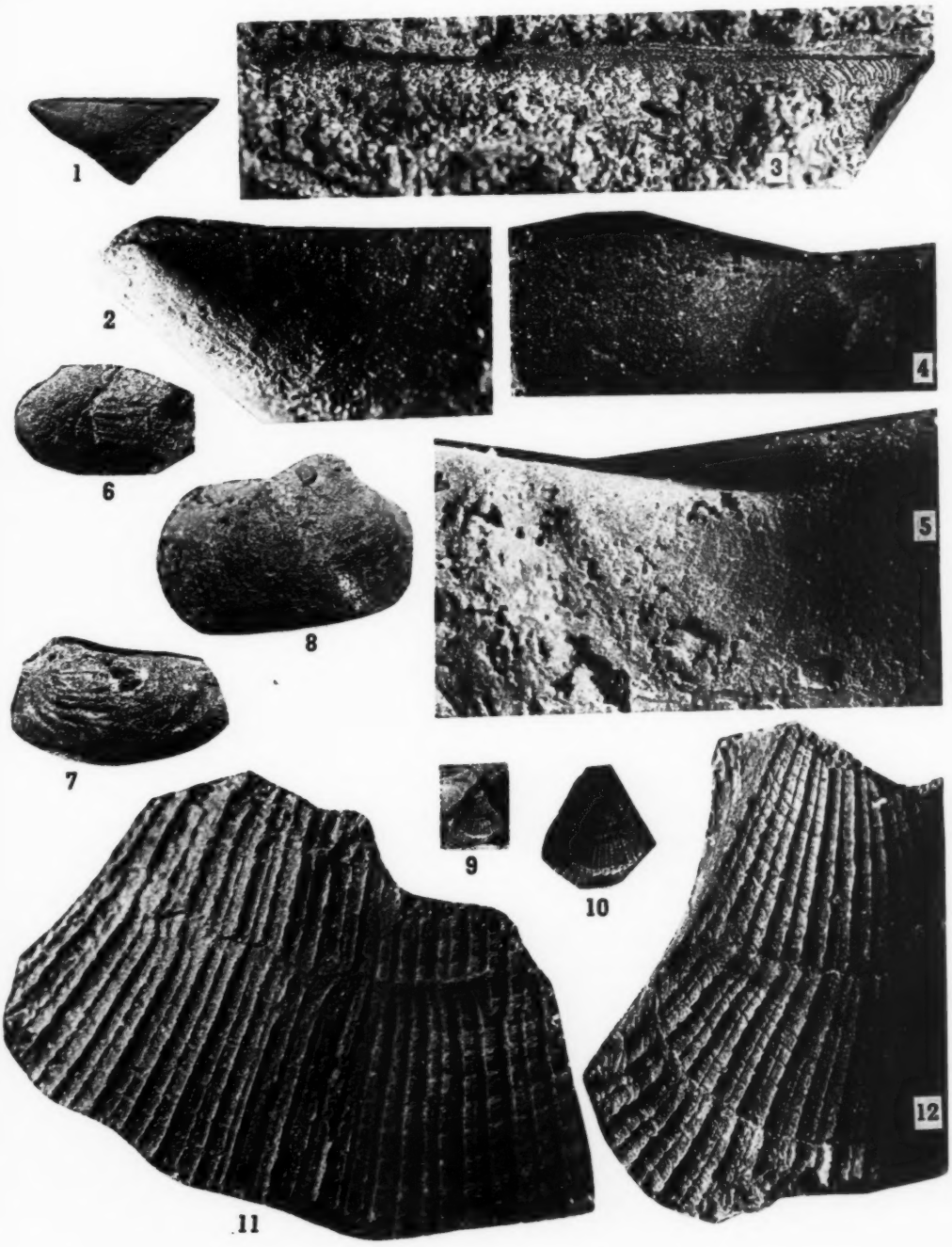
3—*Leptodesma* sp. *A*. External mold of posterior of left valve, ×10.

4,5—*Leptodesma* (*Springeria*) *matheri*, n. subgen., n. sp. Anterior part of internal mold of left valve.

6,7—*Allorisma snideri*, n. sp. Internal molds of two left valves (holotype *7*), ×1½.

8—*Tellinomorpha schencki*, n. sp. Internal mold of right valve (holotype), ×1⅔.

9–12—*Limipecten newelli*, n. sp. *9,10*, External mold of left valve (holotype), ×1 and ×2; *11*, detail of the anterior part of the same valve, ×10; *12*, ventral fragment of external mold of another left valve, ×10.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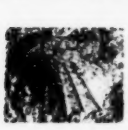
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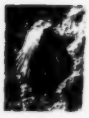
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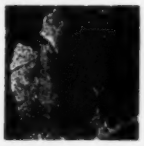
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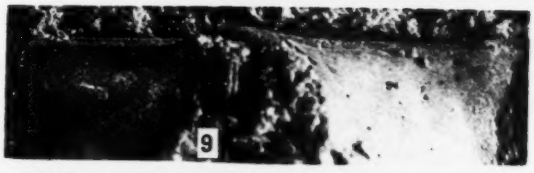
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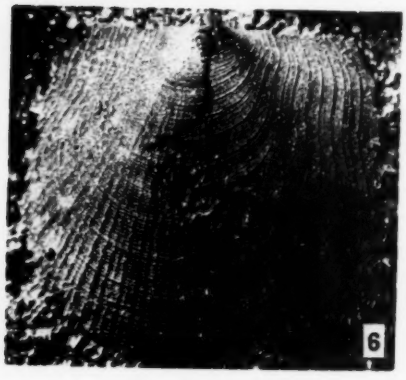
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side of the beak and gently curving anteroventral, till it touches the rear of a faint anterior muscle scar. A weak posterior adductor muscle scar can be observed in a similar position near posterior end of each valve, and a pallial line connecting these scars is also present.

Discussion.—It was mentioned already in generic discussion that *Parallelodon vokesi* belongs in the group of species with the most typically developed and uniformly distributed reticulate or cancellate sculpture. None of such species have been described from the Mississippian of America, where the genus is generally rare. One of the nearest to *P. vokesi* among those described from the Mississippian is *P. multiliratus* Girty from the Moorefield of Arkansas (Girty, 1915, p. 85, pl. XII, fig. 3,4) and the lower part of Caney shale of Oklahoma (Girty, 1909, p. 39, pl. III, fig. 4,4a,5). It differs from *P. vokesi* in having fine radiating costae by far more concentric lirae that are developed in ventral part of the shell. The ventral edge in this form is "rather strongly convex," which is another distinction from *P. vokesi*. Girty mentions but does not describe "some undescribed forms from the Chester [which] have equally fine radii and may prove to be the same, though they are more highly convex" (Girty, 1909, p. 39). It seems permissible to conclude, from this remark, that the form from the Chester is like *P. multiliratus*, even if not identical with it specifically, rather than like *P. vokesi*, n. sp. Another Chester species is *P. micronema* Meek & Worthen (1866, p. 261) from Missouri and Illinois, which is well described but never illustrated by them. According to the description it resembles *P. vokesi* in shape and size, but differs in having only "a few moderately distinct marks of growth . . . near the basal and posterior margins," being in that respect seemingly much like *P. multistriata* Girty. Because it is also quite inflated (convexity about 6 mm., with length 16 mm. and height 7 mm.) *P. micronema* is possibly the identical with Girty's undescribed form from the Chester.

Most similar to *Parallelodon vokesi* is *P. minima*, judging by Weller's (1916, pl. 17, fig. 7) single photograph of this form, originally described by Worthen (1890, p. 124, pl. 20, fig. 4,4a) from the same locality (Ste. Genevieve limestone, Fountain Creek, Monroe Co., Illinois). Weller accepts Worthen's description, "as far as it goes," but states that his "original illustration is not a good representation"; he supplies no new description. *P. minima* needs reinvestigation, and at the present it may be pointed out that it is similar to *P. vokesi* in shape and sculpture, but is ventrally convex and postero-dorsally strongly concave (which adds to posterior convexity), and its beaks are closer to anterior.

Close to *Parallelodon vokesi* in sculpture and shape are some forms from the Old World, which belong to the group with cancellate sculpture mentioned above, but they are all larger in size than *P. vokesi* and *P. minima*. However, among the somewhat heterogenous group of specimens classified by Hind with *P. concinnus* M'Coy, and which are all not much larger than *P. vokesi*, one figured example seems so close to it in all respects (Hind, 1897, pl. XII, fig. 20), that it could be its direct ancestor, if not identical with it. As shown on the sketch, its radiating costae are quite strong, and equal in strength to its concentric fila, although Hind says that *P. concinnus* has

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EXPLANATION OF PLATE 94

FIG. *1,2*—*Acanthopecten grandis*, n. sp. Interior and exterior molds of left valve (holotype), ×2.

3,4—*Streblochondria* (?) *tenuilineata* (Meek & Worthen). External mold of left valve (holotype), ×1; and medial part of another left valve with perfect preservation of sculpture, ×10.

5,6—*Euchondria subquadrata*, n. sp. Exterior molds of an adult and juvenile (holotype) left valves, ×10.

7–9—*Aviculopecten tomlinsoni*, n. sp. *7*, External mold of a complete juvenile left valve, ×1; *8*, detail of sculpture in the postero-ventral angle of an external mold of left valve, ×10; *9*, cardinal portion of internal mold of left valve showing the shape and longitudinal striation of the hinge and widely triangular resilifer (central part partly broken off and exposing a hollow left by dissolution of a crinoidal columnal), ×10.

10—Pseudomonotis (?) sp., ×10.

concentric sculpture and only "obscure radiating ribs," just as he shows so in all other examples of the species (ibid., pl. XII, fig. 16–19,21–22).

In the successive beds of the Pennsylvanian several species belong to this same group and probably evolved from *Parallelodon vokesi*. Next in stratigraphic order above is *P. cancellatus* Mather (1915, p. 215–216, pl. XV, fig. 7) from the upper Morrow of Arkansas, which is only slightly smaller than *P. vokesi*, but has the same shape and "cancellate" surface of the shell. Appearing higher in the Pennsylvanian is a much larger *P. sangamonensis* (Worthen) (1890, p. 123, pl. XXI, fig. 3–3a), which is not too rare in the post-Morrow Pennsylvanian of the Midcontinent (Beede, 1900, p. 146–147, pl. XX, fig. 2–2b, Beede & Rogers, 1908, p. 367; Sayre, 1930, p. 108, pl. IX, fig. 17,17a; and others). Other described Pennsylvanian species of the genus could have developed from the same stock or from other British forms migrating to America. Hind believes, for instance, that *P. tenuistratus* Meek & Worthen from the "Upper Coal Measures" at Springfield, Illinois is "probably identical with *P. semicostatus*" of M'Coy from the highest strata of the Lower Carboniferous and in the lower part of the Coal Measures of British Isles (Hind, 1897, p. 158). Although the size and other characters of British and American forms are indeed very similar Hind's assertions that "the figure and minute description [by Meek & Worthen] agree entirely with the same of the British specimens" needs to be modified. In fact the two forms differ in the way as follows: in British form "the anterior end is small, with its anterior-superior angle pointed," that is, the angle is sharp, varying from 80° to 85°, and the end of the hinge is extended farther than the anterior edge; in American species this angle is obtuse (about 105°), and the hinge is shorter than the anterior edge. Peculiarly, Meek & Worthen's own description of *Macrodon tenuistriatus* (1873, p. 564) does not correspond, in part, with what they show in a well executed drawing and its appended explanation (ibid., pl. 26, fig. 4–4b). Thus, in the descriptive text it is said that "the cardinal area is unknown," while the explanation to figure 4b reads: "Dorsal view of same specimen, showing the convexity of the two valves, the cardinal area, etc." and indeed the drawing shows well developed cardinal areas of the two valves with longitudinal striation over them. Likewise, the descriptive text reads: "anterior side rounding up from below, so as to meet the hinge nearly at right angles," but the side view figure 4a shows a distinctly obtuse angle instead (about 105°). It seems that the descriptive text has been made on a less perfectly preserved specimen than that from which the fine detailed drawing of the plate has been subsequently prepared. Furthermore, the inflation of the British form, judging by the measurement of convexity or "elevation of valve" is proportionally about 1½ as large as in American form. However, it seems that the stratigraphically higher *P. tenuistriatus* of America could have been a slightly changed descendent of *P. semicostatus* of British Isles.

Another suggestive similarity and possible identity is between *Parallelodon tenuistria* M'Coy "confined to the Carboniferous beds of Ireland" (Hind, 1897, p. 152) and the above mentioned *P. multiliratus* Girty from the Moorefield of Arkansas and the lower part of the Caney of Oklahoma, which occurrences are apparently somewhat higher stratigraphically than the species from Ireland. Common are the predominate fine, regular radiating costae, moderate inflation and elongated shape of the two forms, but the form from Ireland is twice the size of that from America.

Genus CONOCARDIUM Bronn

CONOCARDIUM SAYREI, n. sp.

Pl. 89, fig. 10

This is a small form, 3, or possibly 3.5, mm. long and 1½ mm. high. It is reticulate over all surface, in which respect and the triangularity of the lateral outline it is like *Conocardium* sp. *A*. It differs from the latter, however, by its strongly curved and very sharp umbonal ridge and absence of wedge-like elevation next to the ridge on the anterior side—the characteristic feature in *C.* sp. *A*. The details of sculpture on the anterior side are also different, as described below. The description is based on an external mold of a single right valve, which is almost completely preserved.

Posterior is ornamented by equally promi-

nent and narrow radiating and concentric ridges, which produce a striking reticulate pattern, most conspicuous in the mature, ventral part of the valve. Toward the posterior the concentric ridges are much more densely spaced than the radial ridges, so that here the surface loses its diamond-like reticulate pattern so characteristic of the main part of the posterior of the valve. There are 11 subequal radial ribs posterior to the umbonal ridge, but between the umbonal ridge and the ordinary ridge next to it, two additional ridges are intercalated within a gradually expanding wedge-shaped space this side of the umbonal ridge. On the other posterior side of it the surface of the valve bends sharply inward as it becomes strongly concave, and its surface is covered by wide radial ridges divided by equally wide grooves. The concentric ridges are also present, but are developed prominently only when crossing the radial ridges, but not the grooves where they are faint. Thus the ridges are here transversely nodose. Beyond the sharply grooved concavity just next to the umbonal ridge nine radiating ridges can be counted, the last two being low and short, as they are located in the anterior part transitional to the rostrum. The latter is largely broken off, but probably did not extend very far.

The new species is named after A. N. Sayre, the author of the comprehensive study of the mollusks and other invertebrates from the Drum limestone (Missourian Series, Pennsylvanian).

Discussion.—The form seems not too distantly related to *Conocardium* sp. A, but is hardly a young individual or diminutive variety of the same, unless an extraordinary variability of its form is assumed. It is nearer to *C. parrishi* than *C.* sp. *A* in being subequilateral and having curved umbonal ridge, but differs from *C. parrishi* by much narrower umbonal ridge, transversely costate anterior ridges, and having proportionally much greater length (width).

Conocardium irregulare (de Koninck) from the Viséan of Belgium and the Lower Carboniferous Limestone of Seattle, Yorkshire (Hind, 1900, p. 456–458, pl. LI, fig. 12,13), where it is rare, is very similar to *C. sayrei* in the shape and sculpture, and considered "very distinct and peculiarly marked" by Hind; that is, the species is strikingly unlike all other species of *Conocardium*. The only differences of this form from that in the Springer is larger size and fainter concentric lines of growth. Its size is 10 mm. long and 5 mm. high, that is about 3 times that of *C. sayrei*. On the other hand, in spite of its fainter development the sculpture of *C. irregulare* is very much like that in *C. sayrei*, it is distinctly reticulate in the posterior, while it is sculptured only by regularly spaced concentric lines of growth in the anterior. In view of all this it seems logical to regard *C. irregulare* as direct ancestor of *C. sayrei*, the latter being therefore its evolved migrant to America.

Conocardium sp. A
Pl. 89, fig. 11,12

The shell of this species has a triangular outline, the straight hinge serving as longest side of the triangle. The surface is divided by a straight and narrow umbonal ridge that starts from the beak and runs diagonally antero-ventrally. Both the larger posterior and the smaller anterior halves are sculptured by prominent radial ribs and slightly less prominent concentric (transverse) fila, which combine into a striking reticulate pattern.

The dimensions of *Conocardium* sp. *A* are as follows: length 6 mm., height 4 mm., and convexity about 2½ or 3 mm. Radial ribs increase by occasional intercalation, and there are 13 or 14 principal ridges along the ventral edge of the posterior part, that is about as many as in *C. parrishi;* there can be counted from 5 to 6 fila per 1 mm. on this part of the conch. In the anterior part there are three principal ridges that are on the umbonal elevations and three or four more in the rest of the preserved part of the anterior. Fila average 9 per 1 mm. in the part anterior to the narrow umbonal ridge.

The dorsal edge (if this is not an edge of a mechanical break) of the anterior appears concave and much below the hinge line, but it is possible that along this line occurred a break severing off its rostrum. Smaller or larger rostrum is usually developed along the anterior of the hinge, and is frequently broken off. For instance, Girty restored what he believed to be rostrum-less anterior for *Conocardium missouriensis*, but subsequent-

ly Sayre discovered topotype of this form with rostrum preserved, as he reclassified it with *C. parrishi* Worthen.

Discussion.—Among Pennsylvanian species the nearest to it is *Conocardium parrishi* (Worthen, 1890, p. 1102, pl. XX, fig. 7; Girty, 1915a, p. 353, pl. XXVIII, fig. 3–3c, described as *C. missouriensis;* and Sayre, 1930, p. 109–110, pl. IX, fig. 20–20c, who furnished the most nearly complete description and illustration of the form). Following are the differences that set apart the new species from *C. parrishi.*

The latter has no concentric transverse fila over the anterior part of the conch; its umbonal ridge is wider, more conspicuous, curved, and, at least in the better preserved specimens, armed with a row of nodes; the anterior part is equal to or only slightly smaller than the posterior. On the other hand, *Conocardium* sp. *A* has all surface reticulate, and its anterior is only about half as large as the posterior; the umbonal ridge is narrow and straight, but the nearest to it, three narrow ribs of the anterior, are elevated upon a radial wedge-like elevation that takes place of the umbonal ridge; this umbonal elevation grades into the remaining small part of the anterior, which is ornamented with the same kind of ridges and also transverse fila, but all the fila, which are developed anterior to the narrow umbonal ridge, are nearly twice as densely spaced as the fila of the posterior part.

Among the large number of species of *Conocardium* known in the Salem (=Spergen) limestone of Indiana *C. meekanum* Hall is the nearest to *C.* sp. *A*. It has a similar small anterior part (with a moderately extended rostrum), and its cardinal ridge is narrow and no more prominent than the neighboring principal ridges or ribs. Also, both posterior and anterior are covered by ridges and concentric fila, though in the anterior the latter are in form of "nearly obsolete traces of fine striae" (Hall, 1858, p. 15; Cumings & Beede, 1906, p. 1329, pl. XXIII, fig. 21–23). In fact, *C.* sp. *A* may be considered an evolutionary link between *C. meekanum* and *C. parrishi*, but nearer to the former than to the latter. The main character that developed in Pennsylvanian *C. parrishi* is the prominent thick umbonal ridge, a feature seemingly unknown in the Mississippian representative of the genus. However, unillustrated *C. peculiare* Girty, 1910, p. 227, from the Fayetteville of Arkansas is described as having a "broad" umbonal ridge, but it is also said to be ornamented by several costae, a feature reminiscent of the similarly ornamented wedge-like elevation in *C.* sp. *A* here described, and apparently is not a true umbonal ridge.

Conocardium is known in the lower Mississippian (Herrick, 1888, p. 27; Moore, 1928, p. 206; Hyde, 1953, p. 317) and is well represented in the Salem (Spergen) (Hall, 1856; Cumings & Beede, 1915), but unknown or very rare in the Chester of Illinois and adjacent states. One species is known in the Fayetteville of Arkansas (Girty, 1910, p. 227) and the Pitkin of Oklahoma (Snider, 1915, p. 104–105). Other species known in the Batesville sandstone (Girty, 1915, p. 90–91, pl. VII, fig. 7,7a) and common in the equivalent of the Moorefield in Arkansas (Girty, 1915a, p. 34–36, pl. II, fig. 3–6); Easton (1943, p. 132) reports poorly preserved and rare representatives in the Pitkin of Arkansas. On the other hand, it has not been found in the Upper Morrow of Arkansas or Oklahoma (Mather, 1915; Girty & Roundy, 1932). It is recorded in the Marmaton group of the Upper DesMoinesian and the Missourian Series of the northern mid continent (Beede & Rogers, 1908, p. 367).

Genus LEPTODESMA Hall, 1883

Leptodesma HALL, 1883, New Jersey Paleont., vol. 5, pt. 1 (Plates and explanations include several species of the genus); ——, 1884, New York Geol. Survey, Paleont., vol. 5, pt. 1, p. XIII; MILLER, 1889, North Amer. Geol. and Paleont., p. 484; JACKSON, 1890, Boston Soc. Nat. Hist., Mem., vol. 4, p. 381–382; DALL, (In ZITTEL), 1913, Text-Book of Paleontology, 2nd English Edit., p. 444.

Leiopteria HIND (part), 1901, Paleont. Soc. London, vol. LV, p. 9–10.

Type species.—Leptodesma potens Hall, 1883; subsequent designation by Miller, 1899.

Two generic names, *Leiopteria* and *Leptodesma* were introduced simultaneously by Hall for some Devonian aviculoids of America. The essential difference of *Leptodesma* "in its prevailing forms," as he formulated it, is "that the anterior end is always nasute and acute, instead of auriculate and rounded," in *Leiopteria* (Hall, 1884, p. XIII).

Subsequently, a few Carboniferous forms

were classified with these genera, and also doubt was expressed in the need of generic discrimination between the two. Jackson (1890, p. 333,381–382, and 391) who studied Hall's types at Albany, discusses at some length *Leptodesma* and puts it in the direct ancestry of *Avicula* and the large stock of aviculoid pelecypods, while he mentions *Leiopteria* only once (ibid., p. 330), as a genus described together with *Leptodesma* by Hall, and does not place it in his phylogenetic chart. Hind (1901) likewise says: "It seems doubtful to me if both generic names are necessary," but he applies to the numerous described British Carboniferous forms the name *Leiopteria* in preference to *Leptodesma*, though he admits that in shape they "are certainly more nearly like the figured species of *Leptodesma* than *Leiopteria*, and have the elongate process posteriorly common to *Avicula* and the former genus" (Hind, 1901, p. 10). He, like Jackson, sees closest proximity of the Paleozoic genus to recent *Avicula*. Although both Jackson and Hind implied a suggestion to drop one of Hall's names, they did not formally do so and did not put one as synonym or sub-generic division of the other (Hind, 1901, p. 9, puts *Leptodesma* questionably in synonymy of *Leiopteria*).

Besides the differences between *Leiopteria* and *Leptodesma*, as formulated by Hall, there seems to be a general difference in shape, more nearly oblique and with more elongated posterior in *Leptodesma* in contrast with nearly quadrangular with shorter posterior in *Leiopteria*.

With this difference in shape seems to be correlated development of the muscles, which were not discussed by Hall. As Jackson (1890, p. 381) says, in *Leptodesma* "the posterior adductor muscle is large, subcentral, but the anterior is not figured by Hall and is therefore presumably very reduced." Hind (1889, p. 9) in his generic characteristic of "*Leiopteria*" does not mention the posterior muscle but says that "the anterior adductor muscle is small, rounded, deep, placed well within the concavity of the valve, remote from the margin." Dall (1913, p. 444,448) places the two genera in two different families: *Leptodesma* in *Pterineidae* Dall, which has amphidetic ligament and is dimyarian, that is possessing two muscles, and *Leiopteria* in *Pteriidae* Meek, which has alivincular ligament and is monomyarian, that is possessing one muscle, though in young stages is "dimyarian, the anterior adductor disappearing with age" (Dall, 1913, p. 447). If Dall's understanding of *Leiopteria* is accepted, this genus may be considered a side-branch developed from common stock with *Leptodesma* (probably from the Silurian *Rhombopteria* as believed by Jackson), and *Leiopteria* is probably not in direct line of development toward *Avicula*.

In view of all these considerations it is likely that discriminating paleontologists will continue to use both Hall's genera at least for the shells sufficiently preserved to observe details of anterior and muscle scars. On the other hand it seems desirable to choose one of the names in preference to another, when dealing with shells with indistinct anterior and posterior muscle scars, or when discussing the whole group. One of the two names, therefore, must be selected as generic, and the other may serve rather as subgeneric for these purposes. Although *Leiopteria* is the first in order of Hall's description of the two genera, and probably because of this was used by Hind, this fact alone is not obligatory for our selection, and in view of Jackson's choice of *Leptodesma*, which precedes that by Hind, and because *Leptodesma*-like, and not *Leiopteria*-like shells are considered by both Jackson and Hind closely comparable and in direct ancestry to recent *Avicula* and the whole aviculoid stock, I select *Leptodesma* as the genus and *Leiopteria* as its subgenus. This selection automatically makes the genotype of *Leptodesma* s.s. also the genotype of *Leptodesma* in broader sense, including *Leiopteria*. Hall did not indicate genotypes of his genera, but Miller (1889, p. 484) did so. Genotype of *Leptodesma* is *L. potens* Hall of the Chemung, and genotype of *Leiopteria*, *L. dekayi* Hall of the Hamilton.

From the outlined understanding of phyletic relationship between *Leptodesma* and *Leiopteria*, and the taxonomic treatment here suggested, it follows that nearly all British Carboniferous forms described by Hind (1901) under the name *Leiopteria* must take the name *Leptodesma*. Hind already recognized that they are closer to the American Devonian forms classified by Hall as *Leptodesma* than to those classified as *Leiopteria*, as nearly all have rounded and

not acute anterior, and oblique shape. In *Leiopteria* may be left only the minute *L. obtusa* McCoy (Hind, 1901, p. 21–22, pl. V, fig. 15–17), but hardly any others. The American Carboniferous forms of *Leptodesma* s.s. were illustrated only by natural size skteches but seem to be all more nearly like the Devonian *Leptodesma* than *Leiopteria*, while their muscle scars are unknown, and the details of anterior are not clearly indicated. Thus it appears that only very few, dwarfed species of *Leiopteria* survived from Devonian time into early Carboniferous, while *Leptodesma* continued on and gave rise to aviculoid stock.

It seems likely that the presence of "*Leiopteria* (?)" in the lists of Pitkin limestone fossils by Snider (1915, p. 41–43), Croneis (1930, p. 75, quoted from Snider) and Eastman (1943, p. 132) is based on a species of *Leptodesma*. Weller's record of "*Liopteria* sp." (1920, p. 196) in Glen Dean limestone and of "*Liopteria* n. sp." in Fredonia limestone, St. Genevieve formation may be also provisionally changed to *Leptodesma*. The record of *Leiopteria spinulata* (Winchell) from the Kinderhook of Iowa by Van Tuyl (1922, p. 61) must be changed to *Leptodesma* (*Pterinea*) *spinulata* (Winchell). The Spergen series, originally described by Whitfield (1882, p. 56, pl. 17, fig. 1) as *Pteronites spergenensis* (see also Beede, 1906, p. 1323, pl. XXIII, fig. 1), was already transferred to *Leptodesma* by Girty (1927, p. 418), with which I agree.

In 1937 Newell illustrated his "hypothesis as to how the evolution of certain types of ligament systems (in Pectinoids) *might* have preceded" (his italics, 1937, p. 33–34), and in doing so placed the types of the ligament in juvenile "*Leiopteria*, *Ptychodesma*, and the hypothetical ancestral type" (ibid., p. 33) as an earliest or initial stage in this hypothetical evolution. His illustrations are wholly diagrammatic and show both juvenile (ibid, fig. 13-1a) and adult (ibid., fig. 13-1b) types of the ligament in "*Liopteria*" (=*Leiopteria* of authors). There is no information in the text whether he personally examined the type or types of *Leiopteria* Hall, or on what evidence this concept of the ligaments in *Leiopteria* is based. The ligament is shown to be of "chevron" type, that is consisting of a few parallel ridges and grooves gently sloping anteriorly and posteriorly from the center of the hinge, where these sloping grooves and ridges meet at an angle, somewhat like the chevron mark of military ranks. Contrary to the concept of the "chevron" type of ligamental grooves in "*Liopteria*," Hall mentions that in *Leiopteria* the "ligamental area marked by parallel longitudinal striae" (1884, p. XIII), and likewise in *Leptodesma*, he also finds the "ligamental area narrow, extending the entire length of the hinge, marked by fine, sharp, longitudinal striae" (ibid., p. XIII). The described character of parallel striation in the ligamental area of these two genera can be observed also on some sketches of *Leiopteria dekayi* Hall (1884, pl. LXXXVIII, fig. 8) and on those of *Leptodesma longispinus* Hall (1884, pl. XXI, fig. 14) and *Leptodesma nerens* Hall (1884, pl. XC, fig. 31).

The striae in the ligamental area of my shells from the Redoak Hollow are parallel and quite sharp, thus being like those in Hall's examples of *Leptodesma* from the Chumung.

Hall describes also the dentition in both of his genera. In *Leioptera* the "hinge with one or two oblique slender lateral teeth," and in *Leptodesma* the "hinge narrow, furnished with a slender lateral tooth just posterior to the beak and nearly parallel to the hinge line."

In the right valves of *Leptodesma* from the Redoak Hollow there is a distinct though very narrow linear tooth-like prominence that extends from the beak anteriorly and just next to the margin of the hinge. Just under the center of this tooth is a flat but quite distinct anterior muscle scar. Corresponding scar is also developed on the opposite anterior part of the left valves, but no other scars have been found on either left or right valves. Hall shows and mentions a subcentral "muscular impression" in a few valves of *Leptodesma*, and also in his sketch of *Leptodesma nerens* from the Chemung. In addition to the larger subcentral posterior scar in the latter a smaller scar-like impression is apparently also indicated anteriorly, and very near to the spot where the anterior scar is located in the valves from the Redoak Hollow. However, Hall believed that in his shell "the apparent anterior muscular scar is due to a defect in the shell, as the pal-

lial line can be traced to a point just anterior to the beak" (Hall, 1884, explanation to pl. XC, fig. 31). Be as it may, it seems that it is not a mere coincidence that this scar-like mark would occur exactly where an anterior muscle scar should be. Scar-like marks of a very similar size and position are observable also on the sketches of "*Leiopteria thompsoni*" (Hind, 1901, pl. III, fig. 11, and pl. IV, fig. 2,3), although Hind says nothing about them either in the text or in the explanation to the plate. In this species, which seems very similar to the form here differentiated as *Leptodesma stenzeli*, n. sp., there is no posterior muscle scar at all, just as in the just mentioned form from the Redoak Hollow.

The evidence discovered in the discussed shells from the Redoak Hollow seems decidedly in favor of placing them near the original *Leptodesma* Hall rather than *Leiopteria* Hall. But they may also be segregated into a new genus, or perhaps rather subgenus, on the evidence of the development of anterior tooth and anterior muscle scar. Thus, the forms from the Redoak Hollow near Springer can be differentiated under a new subgeneric name *Springeria*. Its diagnosis follows.

Subgenus SPRINGERIA, new subgenus

Shell oblique, pteroid, with straight hinge and the slightly projecting beak nearer to the anterior than to posterior. Anterior acute, posterior broadly rounded below and with large flat wing above. Narrow cardinal area produced far beyond the posterior edge in some species. Only anterior muscle scar is observed being directly below the center of a narrow horizontal anterior tooth of the right valve. Surface partly or wholly covered by sharply elevated concentric lirae.

Summarizing the conclusions, it is here suggested that the genus *Leptodesma* Hall is understood in a broad sense, which would cover *Leiopteria*, as already implied by Jackson (1890), who examined Hall's types. It is further suggested to use *Leiopteria* as a subgenus of *Leptodesma*, whose range seems to be restricted to the Mississippian. A new subgenus *Springeria* is here introduced for the species of *Leptodesma* from the Redoak Hollow. It does not differ from *Leptodesma* externally but differs from *Leptodesma* (*Leptodesma*) by the development of a long anterior tooth, and a large anterior muscle just under the center of this tooth, see the diagnosis above.

LEPTODESMA (SPRINGERIA) MATHERI, n. sp.
Pl. 92, fig. 1–8;
Pl. 93, fig. 4,5;
Text-fig. 1–3–6

Monopteria? sp. MATHER, 1915, Denison Univ. Sci. Lab. Bull., vol. 18, p. 217, pl. XV, fig. 9.

This is the most common among the species of *Leptodesma* in the Redoak Hollow. In its general outline and simple concentric sculpture it is close to *Leptodesma lunulata* (Phillips) from the lower Carboniferous of England, *Leptodesma lichas* Hall from the Chemung of New York, and *Monopteria?* sp. described by Mather from the upper Morrow of Arkansas and Oklahoma, being possibly identical with the latter. It differs from *L. lunulata*, however, in having a broad ligament area extended anteriorly the whole length of the shell, and the posterior end of equally strong ligamental area produced beyond the postero-ventral border of the adult shell. In *L. lunulata* the posterior wing is invariably shorter than the posterior edge of the shell. In the young stages of shell in *L. matheri*, when it is up to 2 or 3 mm. long, the posterior wing is shorter than the posterior edge, but in the subsequent growth stages the growth of the wing is accelerated and its length surpasses gradually that of the shell below. This is apparently also the case in *Monopteria?* sp. described by Mather (1915), as can be seen from the contours of the earlier concentric growth lines. Mather notes this in the growth lines of its later stages, which give him an impression that the hinge line "probably projected farther than the posterior portion of the shell below" (Mather, 1915, p. 217). There is also an apparent difference in the structure of the observable muscle scars in *L. lunulata* and *L. matheri:* in the former Hind observes and illustrates (1901, pl. III, fig. 2,3) a single large subcentral muscle-scar, while in the inner molds of the latter there is not a trace of sub-central scar, but instead in some specimens can be observed a faint but nevertheless distinct large sub-circular scar along the steep anterior slope of the shell, close to its

hinge line and just under the center of its long linear anterior tooth.

The dimensions of the largest and most complete specimen, an outer mold of left valve, are as follows:

Length	13 mm.
Width	5.5 or 6 mm.
Convexity	about 2.5 mm.

The shell of *L. matheri* has a typical pterid outline, with somewhat variable, but generally narrowly-obtuse anterior; the anterior edge starts sub-perpendicularly to the hinge line, but usually makes a gentle anterior bow, thus projecting somewhat beyond the anterior end of the hinge. The greatest height of shell is far to the posterior, about ⅔ of the length of shell from its anterior edge. The posterior sinus is deep, producing a sharp and narrow wing. The hinge is strongly defined, ligament area .6–.7 mm. wide, coarsely and somewhat irregularly longitudinally striated, produced into a rostrum posteriorly. The beak is sharply defined, slightly elevated above the hinge; a single sub-triangular resilifer (?) is located anteriorly to the beak.

Exterior is ornamented by narrow concentric costae, which are more or less regularly spaced, but differ in density according to stages of growth and position in the conch. The coarsest spacing is along the central part of the main body of the shell, and coarseness increases with the age. The coarsest spacing observed is 3 costae per 1 mm.

The shell was sufficiently thick for the development of fairly coarse excavations of two types: *Mazcusodichyon* and *Caulostrepsis*. The height of their casts is 0.2 mm., which apparently must be less than the thickness of the shell.

Discussion.—*L. matheri* resembles Mississippian *Leptodesma* (*Pteronites*) *spergenensis* Whitfield, but is appreciably larger (the largest *L. spergenensis* is circa 8.5 mm. long) and has a less acute posterior wing (Whitfield, 1882, p. 56, pl. VII, fig. 1; also Beede, 1906, p. 1223, pl. XXIII, fig. 1). *Leptodesma occidentale* Girty from the Brazer limestone (Chester) of Idaho is a still smaller and less oblique shell (Girty, 1927, p. 418, pl. 25, fig. 42–44). *Leptodesma carboniferum* Girty from the Batesville sandstone of Arkansas is subtriangular in outline, with a very gentle posterior sinus, but *Leptodesma spergenensis* var. *robustum* Girty from same horizon and locality is nearer to *L. matheri*, though it is larger, has a much smaller posterior wing, and no hinge anteriorly to the beak.

LEPTODESMA (SPRINGERIA) STENZELI, n. sp.
Pl. 92, fig. 9–12

The most striking feature of this species is subcentral position of the beak in an otherwise asymmetrical oblique shell of typical leptodesmid or pterid outline: it has anterior wing rounded, and posterior wing sharply undercut by a well developed sinus. However, this typical character of the shell is being held only in its early growth stages, which can be observed by the pattern of concentric growth lines in the area around the beak. This concentric sculpture begins to fade out when the length of shell attains circa twelve-fifteen mm., and in the following stages of growth the lines of growth are faint to nearly unnoticeable. The shell has subtriangular outline, like in *Leptodesma thompsoni* (Hind) from the Lower Carboniferous of England and *L. extenuatum* Hall from the Chemung, in having similarly strong hinge, which is produced into s straight rod anteriorly. However, the beak in *L. thompsoni* is quite asymmetrically located, being nearer anterior at circa ⅛ of the total length of shell.

The strongly defined hinge has the liga-

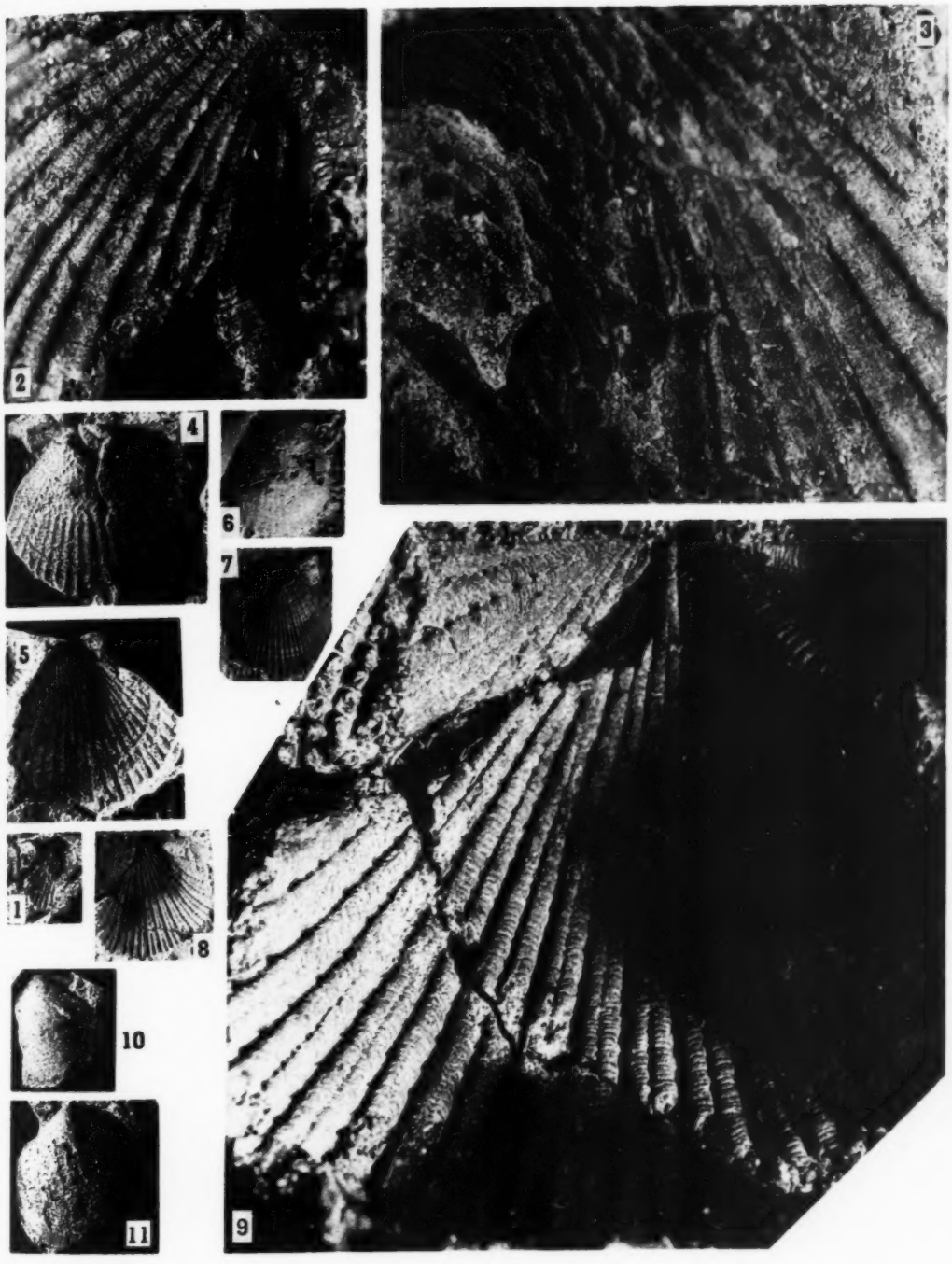
EXPLANATION OF PLATE 95

FIG. *1–5*—*Acanthopecten grandis*, n. sp. *1–3*, External mold of left valve, ×1, and details of the same valve showing the sculpture of anterior and posterior auricles, ×10; and *4*, *5*, internal and external molds of another left valve, ×2.

6,7—*Limipecten newelli*, n. sp. Internal and external molds of an incomplete adult left valve, ×2.

8,9—*Aviculopecten tomlinsoni*, n. sp. External mold of left valve (holotype), ×2 and ×12.

10,11—*Streblochondria ? tenuilineata* (Meek & Worthen). Internal molds of two left valves, ×1.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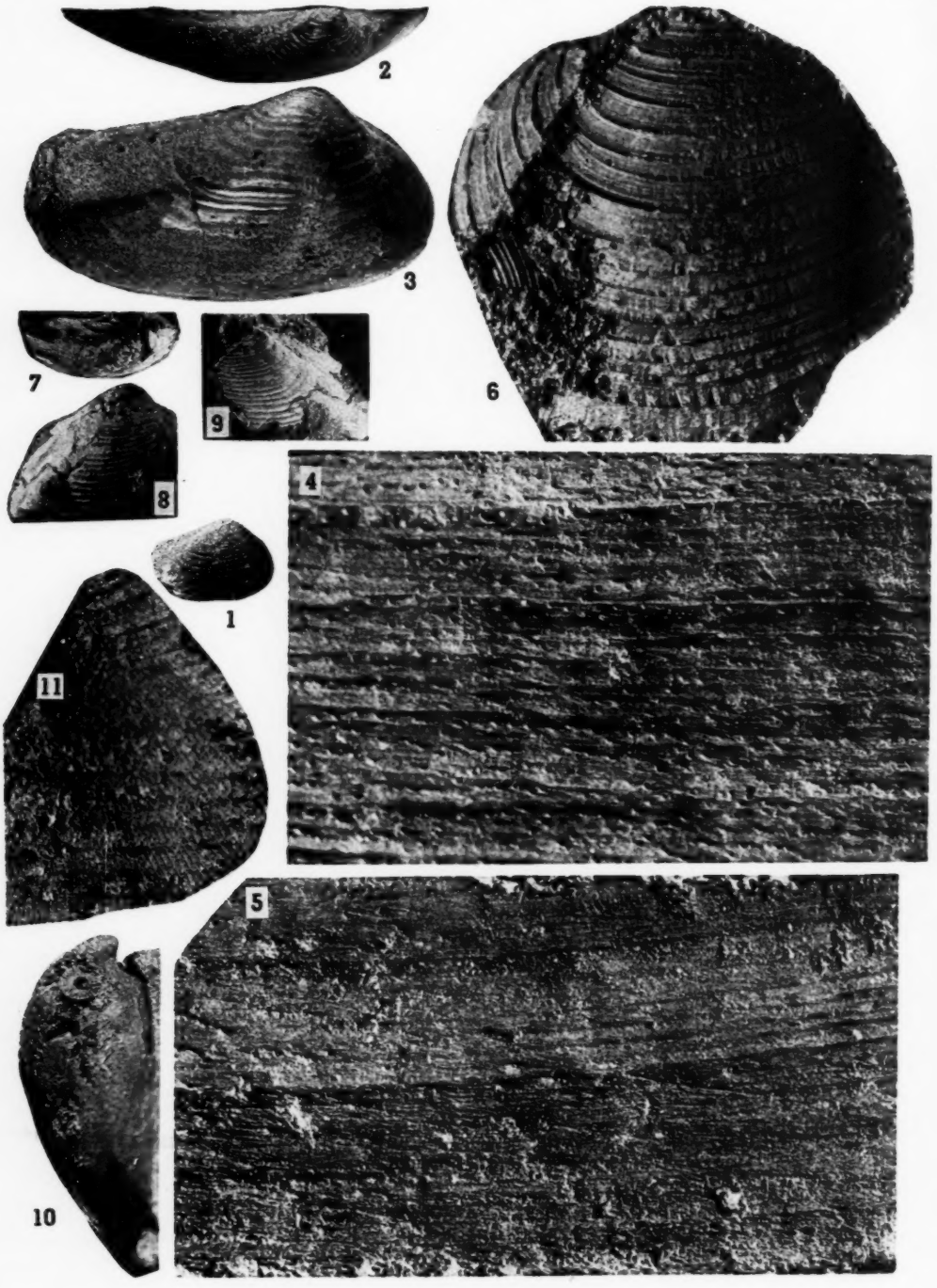
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ment area circa .6–.7 mm. wide, with a number of extremely fine and densely spaced transverse crenulations or teeth in the area anterior to the beak and for a distance circa 1.5–2 mm.; beyond this the ligament area is smooth, except coarsely longitudinally striated, just as is also the posterior part for its whole length. The central part of the ligamental area in both adult specimens broke off in the course of preparation. The shell is prosocline, or forwardly inclined, and its midumbonal line is much inflated in the early stages of growth, but flattens out gradually in the later, adult stages. There is an indication of a faint wide radial groove on the inside of the oblique midumbonal area.

The measurements of the adult left valve (holotype):

Length	12 mm.
Width	5 mm.
Convexity	circa 2.5 mm.

Presence of molds of a few, not very well preserved excavations of *Clinolites* and *Caulostrepsis* type indicates thick shell (more than .2 mm.), the remains of which are preserved in form of very soft spongy dark-brown (limonitic?) tissue. In some areas of the external mold of holotype there can be observed fine reticulate pattern, apparently impression of the prismatic layer of the conch.

External sculpture of earliest stages of growth is in form of concentric costae, the spacing of which becomes gradually coarser in the later stages of growth; but in the adult stage the coarse costae are developed only on the anterior wing, while elsewhere they are very faint, and, besides, between them are developed some lines of growth of almost same prominence. Muscle scars could not be detected on the well preserved inner mold, notwithstanding the fact that the conch is fairly thick.

Leptodesma sp. *A.*
Pl. 93, fig. 3

The form differs from all previously described forms of *Leptodesma* and *Leiopteria* by its extraordinarily long rostrum. Only *Leptodesma* (*Leiopteria*) *longirostris* Hind from the Black Limestone near Castleton of England (Hind, 1901, p. 20–21, pl. IV, fig. 14,15) is somewhat comparable to it in having "a very long rostrum," but while in English form the free part of the rostrum is only about ½ to ⅔ of the total length of the hinge line (judging from the illustrations by Hind) the free part of the rostrum constitutes about ¾ of the total length of the hinge line in *Leptodesma longissima*. Besides, it differs from *L. longirostris* in smaller size and much finer concentric sculpture. However, it has quite comparable outline of the shell, and could be considered a young or dwarfed form of English species, if it were not for the comparatively great length of the rostrum. On the other hand, perhaps the observed length of the rostrum is more of a matter of preservation than a fixed specific character.

Because the anterior half of the single specimen (outer mold of left valve) is not preserved, the dimensions of its total length is inferred. The dimensions are:

Width from apex to end of rostrum	10 mm.
Probable total length	12–13 mm.
Height	2 mm.

According to Hind (1901, p. 20) *Leptodesma longirostris* is stratigraphically restricted to "the zone of *Posidonyma becheri* and *Gly-*

EXPLANATION OF PLATE 96

FIG. *1*—*Sanguinolites omalianus* de Koninck. Inner mold of left valve, ×1.
2–5—*Allorisma maynardwhitei*, n. sp. *2,3*, Top view and lateral view of right valve (holotype), ×2; and *4,5*, details of external sculpture in external mold of the same valve: at anteroventral edge *4* and near center of ventral edge *5*, ×10.
6—*Astartella* (?) aff. *A. concentrica* (Conrad). Outer mold of left (?) valve (holotype), ×10.
7–9—*Sedgwickia rugosa*, n. sp. *7,8*, Top and lateral views of internal mold of right valve (holotype), ×1; and *9*, external mold of the same valve, ×1.
10—*Schizodus chesterensis* Meek & Worthen. Posterior view of internal mold of left valve, ×2.
11—*Sanguinolites* sp. *D*. Part of external mold of same specimen as Text-fig. 16, 17 ×10.

phioceras spirale, G. reticulatum and *G. bilingue*," which places it, in the present understanding of the local stratigraphy and the range of these fossils (if the identifications are acceptable), not lower than the upper Viséan, and not higher than the middle Namurian.

Genus PTERONITES M'Coy (pars)

Pteronites M'COY (pars), 1844, Synops. Carb. Foss. Ireland, p. 81; HALL, 1884, New York Geol. Survey, Paleont., vol. 5, pt. 1, p. xiii-xiv; HIND, 1901, Paleont. Soc. London, vol. LV, p. 5–6 (only the described British and Irish species); DALL (In ZITTEL), Text Book of Paleontology, 2nd English Edit., p. 448.

Some authors do not believe in a necessity to differentiate Upper Pennsylvanian genus *Aviculopecten* Meek from Mississippian genus *Pteronites*, Meek himself being the first to suggest that they are identical, when describing for the first time *Aviculopecten americana*, its type species in some detail. He says:

> "At first I was inclined to place it in the genus *Pinna*, but finding that its beaks, although *very* near the anterior extremity, are yet not exactly terminal, I became satisfied that it could not be propertly referred to that genus, and referred it provisionally to the genus *Aviculopinna*, though later comparisons have led me to suspect that it may possibly be found to belong to M'Coy's genus *Pteronites*, and have to take the name *Pteronites americana*. It has the prismatic shell structure of the allied *Pinna* and *Avicula* groups." (Meek, 1872, p. 198).

Subsequently Hall (1884) referred unhesitatingly to *Pteronites* three American species, *P. profundus, P. rostratum*, and *P. inoptatus*, which he described from the Chemung, the uppermost Devonian of New York and Pennsylvania. There seems to be no reason to question Hall's classification, because not only the structure of his species near its beak is much the same as in the known species of *Pteronites* from the lower Carboniferous of British Isles, but also the outline of the posterior in the adult shell is about as oblique to the hinge line and curved ventrally as in the typical British forms just mentioned. On the other hand, in both American species classified with *Aviculopinna* the posterior of the shell is truncated transversely, with only a gentle, sinusoid swing of the lines of growth. The form described by Hall from the Chemung of New York, and classified as *Leptodesma aliforme* (Hall, 1884, p. 220, pl. XXII, fig. 28; redrawn in greater accuracy in pl. XCI, fig. 2) seems rather very near to *Pteronites latus* as illustrated by Hind (1901, pl. V, fig. 6,7). If transferred to genus *Pteronites*, which seems justifiable, it would constitute the first example of the genus with the interior of the shell preserved and exposed (in form of single mold of a right valve): it has a large subcentral scar of posterior muscle, a distinct pallial line, and an elongated sub-central tooth situated close to the hinge line. It seems that the right valve here described as *Pteronites* cf. *P. angustatus* M'Coy, belongs decidedly to *Pteronites* rather than to *Aviculopinna*, though its posterior is not quite as sharply oblique as in the older species of the genus from America and elsewhere. It seems clear, furthermore, that the form from the Redoak Hollow shows a distinct evolutionary tendency toward the upper Pennsylvanian genus *Aviculopinna*, but is certainly morphologically nearer to *Pteronites*. Thus at the present it constitutes the highest known occurrence of genus *Pteronites* in America, from which probably *Aviculopinna* evolved sometime in the late Morrow or somewhat later Pennsylvanian time. Further discussion of the genus is at the end of the following description of *P.* cf. *P. angustatus*.

PTERONITES cf. P. ANGUSTATUS M'Coy
Pl. 93, fig. 1,2;
Text-fig. 1—8

Pteronites angustatus M'COY, 1844, Synops. Carb. Foss. Ireland, p. 81, pl. XIII, fig. 6; HIND, 1901, Paleont. Soc. London, p. 7–8, pl. V, fig. 1–5.

Pteronites naviformis DE KONINCK, 1855, Ann. Mus. Roy. Hist. Nat. Belge, vol. 9, p. 187, pl. XXX, fig. 26.

Pteronites subventricosus DE KONINCK, 1855, Ann. Mus. Roy. Hist. Nat. Belge, vol. 9, p. 186, pl. XXX, fig. 25.

Only one example of an apical portion of a right valve has been recovered, in form of well preserved external and internal molds. It is 16 mm. long and 7 mm. wide, with an angle between the straight hinge line and slightly wavy ventral edge about 40°. The growth lines traverse the valve at about 50° to the hinge line, and swing in a broad curve

when nearing ventral edge. The acutely angular beak rises only a shade above the hinge, and in front of it is an extremely narrow anterior wing about 0.4 mm. wide at the hinge line. Minute round depression located in this wing just below the hinge may be a scar of a rudimentary anterior muscle. The smaller rounded fragment of the valve in postero-ventral position to the main apical fragment may be the posterior muscle scar, compare with that in *Pteronites aliforme* (Hall) from the Chemung discussed above. Thus the information from the two American species supplies, at least in part, the long delayed information on the interior of the genus established on British material (Hind states, 1901, p. 6, that its "interior is unknown").

Although the calcareous substance of shell is not preserved, a very delicate honeycomb limonitic infiltration into the interstices of the prismatic layer indicates unmistakably that such was the structure of the shell. The prismatic structure is one of the most characteristic features of the shell of *Pinna* and its kin, such as *Aviculopecten* and *Pteronites* (Meek, 1872, p. 198).

Genus SEDGWICKIA M'Coy

Sedgwickia M'COY, 1844, Synòps. Carb. Foss. Ireland, p. 61; MEEK & HAYDEN, 1865, Smiths. Contr. Knowledge, No. 172, p. 38–42 (the genus is discussed , but American species are only questionably referred to it and none is retained in it in its subsequent revision by HIND, 1899, p. 278); HIND, 1899, Paleont. Soc., vol. 53, p. 277–286; pl. XXVI, pl. XXVII, fig. 1–14.

The genus is closely related to *Schizodus* and, in the past, several attempts were made at recognition of *Sedgwickia* among American shells. However, the originator of these attempts, F. B. Meek only questionably placed in this genus four species: *S.* (?) *topekaensis* (Shumard), *S.* (?) *concava* M. & H., and *S.* (?) *altirostrata* M. & H. (Meek & Hayden, 1864, p. 40–42), and later also *S.* (*Singuinolites?*) *subarcuata* (Meek & Worthen, 1865, p. 251; 1868, p. 537). In his own words about the latter species which is from the Keokuk of Illinois Meek says: "Nothing can be determined in regard to its hinge, nor have we any means of ascertaining the nature of its muscular and pallial impressions. Possibly we should call it *Allorisma subarcuata*." Lack of information about these same characters induced Meek to put question mark behind the other three generic references for the species, all of which belong to the Upper Pennsylvanian of the northern midcontinent. Although some other Pennsylvanian specimens of *Sedgwickia* were subsequently identified in America (for instance by Beede, 1900 and 1908) no attempt was made to better our knowledge on their hinge and revise their generic status, and therefore all four of them can be placed in *Sedgwickia* only in the same provisional way as entertained by Meek; and to all of them are still applied Hind's expression of "great doubts whether any of the three species included by these authors [Meek & Hayden] in the genus really belong to it" (Hind, 1899, p. 278).

Taking all this into account it appears that the present classification with *Sedgwickia* of the species from the Redoak Hollow, which is based on both external characters and structure of hinge is the first one in America thus substantiated.

Although Meek & Hayden characterize the hinge in genus *Sedgwickia* as "edentulous," Hind, who revised the original M'Coy's species and described additional species of his own, emends M'Coy's part of definition of the genus in regard to its hinge thus: "Hinge edentulous, or with a single small cardinal tooth in the left valve" (Hind, 1898, p. 277). He further adds (p. 278) that "the presence of a small cardinal tooth in at least one species of the genus [*S. ovata* Hind] emphasizes the relationship between *Schizodus* and *Sedgwickia*," which "has a very close resemblance to *Sedgwickia*, but the latter genus is distinguished by its characteristic surface-markings, the endentulous hinge or single small cardinal tooth, smaller degree of obliquity, and the fact that the umbones are not at all prosogryous," that is directed forwards (p. 277).

Only one correction should be introduced in Hind's generic emendation: A cardinal tooth, when developed, is in the right and not the left valve—see Hind's own description of it in species *S. ovata*, and, particularly, the illustration of the single small tooth in its *right* valve (ibid., p. 281, pl. XXVII, fig. 1a). The presence of a similar small tooth in *Sedgwickia rugosus* from the Redoak Hollow is in harmony with this cor-

rection and in fact is the best proof that our species truly belongs in this genus; it agrees with it in all other characters, such as the shape and, particularly, the well developed characteristic sculpture. It seems quite possible, as Hind hints, that similar tooth will be found in other species of *Sedgwickia*, whose structure of hinge is at the present poorly known.

The above mentioned correction for genus *Sedgwickia* in regard to the presence of tooth in right and not left valve raises a new problem as to how to differentiate this genus from *Schizodus* when only dentition of right valve is known for a species, as in the case of *S. rugosum*, n. sp., because *Schizodus* too is characterized by the presence of one tooth in its right valve. It appears that the distinction is only in size of tooth relative to a size of valve: tooth is small in *Sedgwickia* and large in *Schizodus*, the larger size in the latter being apparently a consequence of the development in it of a pair of teeth in its left valve, the right valve tooth becoming interlocked in the socket between the teeth of the left valve. This situation implies also that the tooth of right valve in *Schizodus* is not a mere bump-like elevation like that in *Sedgwickia*, but it is more elevated and more elaborate structure capable of fitting into a narrow space between the two left valve teeth, see Text-figure 1. It is understood that no teeth are present in left valve of *Sedgwickia* which is edentulous.

SEDGWICKIA RUGOSA, n. sp.
Pl. 96, fig. 7–9;
Text-fig. 1–13

This species is represented by a single, somewhat incomplete, but otherwise well preserved right valve. Because the shell itself is destroyed, only the external and internal casts are available, but they reflect faithfully all details of the external and internal surfaces of the shell.

The shape of the shell is quite typical of *Sedgwickia* and this generic classification is further sustained by the presence of characteristic type of hinge with a small, horizontally projecting tooth, typical of the genus.

The valve is fairly large, with length (restored) near 35 mm., height about 24 mm., and convexity near 10 mm. The new species is closely comparable to *Schizodus wheeleri* (Swallow) in shape and size, especially as shown in the specimen from the Pennsylvanian of Indiana identified and illustrated on pl. 30, fig. 3, by White (1883; reprinted by Keyes, 1894, pl. 46, fig. 3c; Beede, 1900, pl. 22, fig. 1b). However, it differs from it conspicuously in the prominent sculpture of the shell. The shell of *S. rugosa*, n. sp., has not only fine concentric lines of growth as in *S. wheeleri*, but also regularly spaced concentric costae over the central and anterior parts. This sculpture starts at the beak and continues to the edges of an adult shell, the costae becoming gradually more distantly spaced, but increasing little in prominence. The costae at the edge of the middle of adult shell are 1.5 mm. apart. The shell is very thin and the concentric costae are reflected on the inside with almost same sharpness as on the exterior, which makes the conch corrugated. No muscular scars or pallial line can be discerned.

Posterior is clearly separated from the middle part by the sudden subsidence of the costae along the slightly curved diagonal ridge, formed by accelerated curvature of the valve. This ridge is bordered posteriorly by a shallow groove. Beak is strongly incurved. The prominent corrugation of the shell, somewhat reminiscent of plications in *Allorisma*, make the species unique, and hence one of the most characteristic forms of the Redoak Hollow.

Discussion.—There seems to be no other American species of *Schizodus* or *Sedgwickia* with similarly corrugated conch. A few species of *Schizodus* are known to have more or less regularly spaced concentric striae (*S. arkansanus* and *S. batesvillensis* of the upper Mississippian), but they resemble the costae of *S. rugosa* only in spacing, but not in prominence, and, besides, these species have a much more elongated conch. Other Mississippian species approach *S. rugosa* in shape and size, for instance *S. chesterensis* and *S. depressus*, but their surface is smooth and marked only by faint lines of growth.

Sedgwickia rugosa stands closer to Scottish *S. scotica* Hind than to any known American species of *Sedgwickia* (?) and *Schizodus*. The right valve from the Redoak Hollow is particularly similar to the right valve of *S. scotica* illustrated by Hind on pl.

XXVI, fig. 5, as "a medium-sized example, from the Lower limestone series of Bath," that is Zone C or lower Viséan. It measures (on the sketch) 30 mm. wide and 24.5 mm. high, that is practically the same measurement as can be visualized in our restored valve (pl. 96, fig. 8). Furthermore, the concentric sculpture is also about the same, about 3–3½ undulations per 2 mm. in the adult part of the valve. In fact the only difference between *S. rugosa* and *S. scotica*, as exemplified by the mentioned specimen from Scotland, is a sharper expression of the umbonal ridge in our form, though perhaps even in this respect the difference may be small, if Hind's larger specimen of *S. scotica* illustrated on his pl. XXVI, fig. 6, truly belongs to this species—some doubts may be entertained about it.

Be as it may, there can be hardly any doubt that *Sedgwickia rugosa* is closely related to *S. scotica* and furnishes one of the best evidences of migration of a group of British pelecypods to America at the end of Dinantian (Lower Carboniferous) time.

Genus SCHIZODUS King
SCHIZODUS CHESTERENSIS Meek & Worthen
Pl. 96, fig. 10;
Text-fig. 1–9,10

Schizodus chesterensis MEEK & WORTHEN, 1860, Proc. Acad. Nat. Sci. Philadelphia, p. 457; ——, 1866, Illinois Geol. Survey, vol. 2, p. 301, pl. 23, fig. 6a,b.

Valve about 1⅓ as wide as high, broadly rounded anteriorly, attenuated posteriorly. Umbonal ridge, which is distinctly marked by a turn of the growth lines, starts from the beak and extends diagonally with a very gentle downward sag to the postero-ventral corner. Umbo located about ⅔ of the total width from the anterior edge, somewhat incurved, and only slightly above the gently curving hinge. Exterior ornamented only by obscure concentric lines of growth, some of which are stronger than the other and more evenly spaced, and all fading out toward the umbo.

A well preserved umbonal part in the internal mold of the left valve from the Redoak Hollow demonstrates the presence of a smaller anterior tooth, and a larger bilobate posterior tooth, the socket between them apparently accommodating the single tooth of the right valve. Short curved hinge slopes anteriorly and posteriorly from these teeth, the whole hinge structure being quite typical for genus *Schizodus*.

Besides the just mentioned dentition, all other features in the single recovered valve, represented by both external and internal molds, are very much like those in the previously described and illustrated valves of the species. Distinct sub-circular anterior and posterior muscle scars are well indicated in a position about half-way from the beak and farthest anterior and posterior points of the valve respectively.

Discussion.—Presence of dentition characteristic of the genus has not been found but merely inferred in *Schizodus chesterensis* and in related *S. wheeleri*. Although *S. chesterensis* and *S. wheeleri* are customarily treated as separate species, apparently no attempt has been ever made to point out in which way they can be distinguished between themselves. It seems that it was merely assumed that the first occurs in the Mississippian, and the second in the Pennsylvanian. Finding in the Redoak Hollow of a form which can be, with nearly equal propriety, classified with one or the other of these two species served an incentive for the present comparative review of these two, and also of other related species.

It seems that only one character can be safely used for differentiation of *Schizodus chesterensis* from *S. wheeleri*, and this is outline of their posterior. In *S. chesterensis* both postero-dorsal and postero-ventral margins are about equally convex, and their junction makes a rounded acumination comparable to that of the sharper end of an egg. In *S. wheeleri* these margins meet at a sharper angle, and besides the whole posterior becomes dorso-ventrally truncated, as the dorso-ventral margin becomes sub-angular instead of evenly convex in *S. chesterensis*. In this respect the valve from the Redoak Hollow is decidedly like that in *S. chesterensis*.

Schizodus chesterensis from the Maxville limestone (Upper Meramecian) of Ohio, described by Whitfield is not identical with these species, however, as its posterior is quite different, a fact which Whitfield himself noticed. He says that the described

specimen was identified and labeled as *S. chesterensis* by F. B. Meek, and thus he classifies it so, but the "lines of growth would indicate a shell with a much higher posterior end than those cited [for shells of *S. chesterensis*], and when better material is obtained it may be necessary to give it another specific name" (Whitfield, 1895, p. 474; republished from 1891). The posterior of this form, which even with the information at hand, is certainly not *S. chesterensis*, but a new species has its posterior formed by a long horizontal hinge, which is truncated by a nearly straight, inclined about 110° to its postero-dorsal margin. This shape of posterior perhaps would be most characteristic.

Schizodus batesvillensis from the Batesville and the Moorefield of Arkansas, which correlate with lower Chester and St. Genevieve of Illinois, could be ancestor to *S. chesterensis* of the Pitkin and the Upper Chester of Illinois, where the original of the latter was collected (Meek & Worthen, 1860 and 1866). The posterior outline of *S. batesvillensis* is as symmetrically obovate as in *S. chesterensis*, but is more attenuate, the whole shell being more transverse.

Schizodus axiniformis Phillips is the nearest to *S. chesterensis* among British Lower Carboniferous species of *Schizodus*, but it is nearly twice as large, and its umbo is proportionally much closer to its anterior.

Sedgwickia ovata Hind (1899, p. 281) resembles *Schizodus chesterensis* closely in size and shape. However, genus *Schizodus* differs from *Sedgwickia* "by its characteristic surface-markings, the edentulous hinge or single small cardinal tooth, small degree of obliquity, and the fact that the umbones are not at all prosogyrous" that is curving toward anterior (Hind, ibid., p. 277). The umbones and hinge in our material are sufficiently well preserved to show that it belongs to *Schizodus*, and not to *Sedgwickia ovata* or other species of *Sedgwickia*.

Genus AVICULOPECTEN M'Coy
AVICULOPECTEN HALENSIS Mather

Aviculopecten halensis MATHER, 1915, Denison Univ. Sci. Lab. Bull., vol. 18, p. 223–224, pl. XV, fig. 17; NEWELL, 1937, Kansas Geol. Survey, vol. 10, p. 59–60, pl. 5, fig. 5,6.

The subsequently described *Aviculopecten tomlinsoni*, n. sp., is so closely related to this species that perhaps its only distinction is larger size, up to 1½ that of *A. halensis*. This latter species is here discussed because Newell in his revision of the originals, on which Mather established this species and the concurrent *Aviculopecten arkansanus*, suggests that the two are "probably" or even "quite likely" conspecific (Newell, 1937, p. 59,60). This opinion is based on the examination of the single left valve (holotype) of *A. arkansanus*, whose outer surface is embedded in a matrix, but nevertheless can be examined because of semi-transparency of the thin shell, especially when immersed in a liquid (Newell used xylol). As Newell points out, Mather overlooked the presence of the thin shell in the matrix and described the specimen as an "impression of a left valve" (Mather, 1915, p. 280), a cast from which he photographed. The published photograph of the cast shows very distinctly a series of prominent radiating costae of first order (14 or 15), between the central group of which are intercalated costae of second order (at least four). These costae do not seem to extend to the apex of the valve, as would be proper for internal surface of a valve, and Newell indeed is justified in concluding that the shell is "plicated," that is its costae are actually radiating folds within the whole thickness of the shell. However, if this is truly the case in *Aviculopecten arkansanus* then the latter cannot be conspecific with *Aviculopecten halensis* because the left valves of the latter are not plicated. Neither Mather nor Newell could have had any knowledge of this because of the apparent absence of internal molds of the left valves at their disposal. The material from the Redoak Hollow, however, includes a number of complete sets of external and internal molds of left valves of *Aviculopecten tomlinsoni*, which is closely related to *A. halensis*, and they are all invariably internally smooth, hence the shell is not plicated.

A possibility should not be overlooked, indeed, that in the plicated valve of the holotype of *A. arkansanus* only the outer ostracum, made of calcite, is preserved, and that its inner, aragonitic ostracum could have been destroyed. If so, a question may arise whether the supposed inner ostracum was or was not involved in radiating folds of the outer ostracum. Cross-section of left valve of *Aviculopecten arctisulcatus* (Newell, 1937,

p. 50, fig. 21) indicates that the inner ostracum in this particular species was not involved in the plications of the outer ostracum, which is the only ostracum preserved —but it seems that no special investigation has been made by him as to the constancy of such restriction of plications to outer ostracum only, in the revised species of genus *Aviculopecten*. Hence it seems that at the present level of our knowledge *Aviculopecten arkansanus* may be still considered provisionally as separate species, whose difference from the very similar *A. halensis* is that its left valve apparently is plicated. Perhaps further difference is in the smaller number of radial costae counted at the same distance from the beak: at 6 or 6½ mm. from beak there are altogether 24 costae in *A. halensis* (and also in *A. tomlinsoni*), but in *A. arkansanus* there are only 14 to 15 costae of first order plus 4, or possibly up to 6 of second order, as far as can be seen on Mather's photograph (1915, pl. XV, fig. 13); this number is compatible with Newell's count of the costae with the aid of xylol: "20 body costae, of which at least 9 are intercalaries" (Newell, 1937, p. 60). In this respect *A. arkansanus* is much like *Aviculopecten eaglensis* from the Eagle limestone of the Pottsville of West Virginia (Price, 1916, p. 719, pl. 31, fig. 1,2; Newell, 1937, p. 54, pl. 4, fig. 1,2, reproduced from Price), and is possibly conspecific with it.

AVICULOPECTEN TOMLINSONI, n. sp.
Pl. 94, fig. 7–9;
Pl. 95, fig. 8,9

Several sets of outer and inner molds of left valve have been recovered, most having the sculpture excellently preserved. The valve shows but little anterior inclination (it is almost acline), is only slightly longer than high, and its auricles are sub-equal, though of different shape and sculpture. Anterior auricle has a sygmoidal edge, while that of posterior auricle is merely broadly concave, and in combination with straight hinge produces a fairly acute posterior rostrum.

Mature left valve is to 10 mm. high, and to 11 mm. long, with convexity to 3 mm. The hinge is 8.5 or 9 mm. long. The sculpture consists of prominent radiating costae which are separated by flat spaces about 2 times as wide as the costae. Costae of second and third order intercalate at somewhat variable distances from the beak. There are altogether 24 costae at the distance of about 6 mm. from the beak.

The flat spaces between the costae are traversed by sharply outlined growth lines, which are spaced somewhat irregularly, but average about 10 per 1 mm. in the mature part of valve. When about to traverse the costae most growth lines nearly fade out, but a few growth lines, on the contrary, are intensified into spine-like hooded lamellae, thus producing upon the costae more or less regularly spaced adpressed spines. There are about 3 such spines per 1 mm. at about 5 mm. distance from the beak, and about 2 spines per 1 mm. at a distance of 8–9 mm.

Auricles are traversed by both radial costae and growth lines, and only along the prominent fold of the sulcus, which separates the anterior auricle from the main part of the valve, the costae are quite absent, while the growth lines become very conspicuous and more widely spaced than elsewhere in the valve. Five costae traverse anterior auricle, the central costa most prominent, while the extreme lateral costae are barely discernible.

Growth lines which traverse posterior auricle are most densely and most regularly spaced than elsewhere in the valve: about 12 per 1 mm. They are traversed by two prominent costae, the lower being more conspicuous and adorned with the largest and more widely spaced adpressed spines. On either side of this pair of costae is an additional very faint costa.

Posterior auricle runs into the main part of the valve imperceptibly, and below this auricle the nearly straight edge of the valve is ornamented by a row of at least five or possibly six long parallel spines, which point downward at an angle of 60° to the edge and in the plane of the valve. About 7 or 8 lines of growth converge as they enter into each of these spines. Those spines break off easily in the course of preparatory work and in some valves were probably broken off at the time of deposition and burial in the sediment.

Interior of left valve smooth. The hinge area is very narrow and marked by few longitudinal (not chevron-like) striae. Shallow depression of resilifer has a broad triangular outline typical for *Aviculopecten*.

A small right valve was recovered which apparently belongs to *Aviculopecten tomlinsoni*. Its posterior auricle has the same kind of sculpture as the corresponding auricles in the right valves of *Aviculopecten exemplarius* and *A. occidentalis* illustrated by Newell (1938, pl. 3, fig. 3,9; pl. 4, fig. 5a,6,10, and 11). The peculiarity of this sculpture is the development of radial costae only over the cardinal (dorsal) half of the auricles. In the right valve from the Redoak Hollow the upper half of the posterior auricle is traversed by three low radial costae, which are divided from each other by wide and gentle lirae. This radial sculpture is traversed by sharp very narrow and regularly spaced transverse (concentric) costae. These end abruptly just beyond the ventral slope of the ventral radial costa, and the ventral half of the auricle is practically smooth, with only a few faint and irregularly spaced concentric wrinkles over its surface. The main body of the conch is also nearly smooth, and traversed only by faint radial costae separated by broad flat intervals. This right valve probably belongs with the left valves of *Aviculopecten tomlinsoni*, many of which were recovered from the same slab which yielded the described right valve.

The left valve of *Aviculopectin tomlinsoni*, as described above in some detail, appears to have somewhat more complex sculpture than that in *A. halensis*, as the latter was illustrated and described in detail by Newell (1937, p. 59). However, the material at his disposal and originally collected by Mather (1915, p. 223) could have been originally incomplete, particularly in regard to the set of fragile posterior spines. On the other hand the development of these spines could have been correlated with the larger size of *A. tomlinsoni*, and together with its size could be therefore considered as its specific distinction from the stratigraphically later *A. halensis*.

AVICULOPECTEN sp. *C*.
Pl. 97, fig. 1

Only a single fragment of an outer mold of a presumably left valve of this form has been recovered, but it has such a peculiar sculpture, different from any previously described for the known late Paleozoic pectinoid shells, that at least its specific differentiation from them all seems quite certain. This sculptural distinction consists in sharp zig-zagging of the very prominent and more or less regularly spaced growth lines across the narrow and subequal radiating costae (pl. 97, fig. 1, right side).

The fragment of the external mold seems to represent the anterior part of left valve and basal part of anterior auricle, or rather the fold of the sulcus which separates this auricle from the main part of the valve. This fold is ornamented by prominent growth lines, which are spaced wider than at the adjacent main part of the valve—the relationship being much the same as in the corresponding parts of the left valve in *Aviculopecten tomlinsoni*. The outline of the growth lines in the juvenile part of the valve, and also the radiating costae are also similar in these two species. But in the adult half of the valve the sculpture becomes quite different, as partly described above. The number of costae in species *C* increases by intercalation at a faster rate than in *A. tomlinsoni*, so that whereas in the latter there are about 3 costae per 1 mm. at a distance of 5 mm. from the beak, in species *C* there are about 5 costae per same space and distance. Furthermore, while in species *C* the costae of various orders are of about the same strength, the difference in strength of the costae of first, second, and third order in *A. tomlinsoni* is fairly pronounced.

The overall size of left valve in species *C* was apparently not much different than that in *A. tomlinsoni*, that is in the neighborhood of 10 mm. in length and height. While none of the known American late Paleozoic pectinoids resembles species *C*, the British Lower Carboniferous from *Aviculopecten dissimilis* (Fleming) has the same zig-zag kind of transverse sculpture superimposed upon subequal radiating costae of left valve (Hind, 1903, pl. XIII, fig. 1,3, and others). Similar is also the development of ordinary concentric lines of growth in the juvenile part of the valve in the British species, and its change to the zig-zag sculpture starting at a distance of about $\frac{1}{3}$ to $\frac{2}{3}$ of the total height of the mature valve from its beak. However, the British form is about 5 times as large as species *C*, being up to 61 mm. high and 56 mm. long.

Genus LIMIPECTEN Girty

LIMIPECTEN NEWELLI, n. sp.
Pl. 93, fig. 9–12;
Pl. 95, fig. 6,7

The holotype is a mature left valve, with body size 8 mm. long and 8½ mm. high, hinge probably about 7 or 7½ mm. long. Anterior wing traversed by four radiating, curved, spinose, equally prominent costae, while a faint fifth curved costa, spaced at the same distance from the other four, traverses the sulcus. Posterior wing sharply angular, traversed by one strong spinose costa. Main body of valve traversed by 25 prominent narrow costae, 13 or 14 of which are of first order. A few faint ribs of third order are developed among posterior costae. Concentric lamellae (modified lines of growth) quite distinct and more or less regularly spaced, averaging about 6 to 10 per 1 mm. Some of the lamellae in the most mature part of the valve produce sharply pointed crenulations along the major costae, a sculptural detail typical for genus *Limipecten* (Newell, 1937, p. 67), other generic characters being the regularity in spacing of the concentric lamellae, and the method of multiplication of radial costae by intercalation.

The new species is clearly distinct from all previously described ones (see detailed summarized account by Newell, 1937–38, p. 69–71, pl. 9,10). The nearest to it in the character of sculpture is *Limipecten morsei* from Kendrick shale ("high in the Pottsville") of Kentucky (Newell, 1937–38, p. 69–70, pl. 10, fig. 5–7b), but *L. newelli* is many times smaller than *L. morsei* and could be its ancestor. There seems to be a probability that *Aviculopecten arkansanus* (Mather, 1915, p. 226; pl. XV, fig. 13) belong rather to *Limipecten* and is related to *L. newelli*, but differing from it in smaller number of radial costae (15) and much fainter concentric lines of growth. However, Newell retains Mather's species in *Aviculopecten*, though he states that examination of its sculpture is obscured by the immersion of the outer surface in a matrix, which necessitates its observation from the inside, through the thin, semi-transparent shell under xylol, glycerin, or other liquid (Newell, ibid., p. 60).

Genus ACANTHOPECTEN Girty

Acanthopecten GIRTY, 1903, U. S. Geol. Survey, Prof. Paper 16, p. 417; ——, 1903, U. S. Geol. Survey, Prof. Paper 58, p. 437; ——, 1915, U. S. Geol. Survey, Bull. 544, p. 134.

Original concept of genus *Acanthopecten* introduced by Girty was expanded by Newell to include two species of *Aviculopecten*, which were described by Girty but not included by him under *Acanthopecten*. Both are from the upper Permian of Texas and both lack the most characteristic feature of *Acanthopecten*, as understood by Girty: serration of ventral margin "by reason of the shell projecting in large spine-like points from the sulci between the plications" (Girty, 1915, p. 135). Instead, the ventral margins of these two forms, *Aviculopecten laqueatus* Girty, and *A. delawarensis* Girty are evenly rounded. However, Newell (1937–38, p. 75–76) decided to refer them to *Acanthopecten* because they preserve "constant number of costae during ontogeny," and possess a "distinct keel or costella" upon each costa. Presence of the latter feature, in Newell's reasoning, is particularly important in placing the two species with this genus, as "the peculiar keeled costae are found only in *Acanthopecten*."

In view of the abundance in the Redoak Hollow of a typical *Acanthopecten* Girty it seems important to point out that only its most typical species, or those for which Girty introduced the genus, range throughout the Pennsylvanian only, starting from the Redoak Hollow. On the other hand, the less typical species of the genus, placed in it under its broader understanding suggested by Newell are restricted to post-DesMoines Pennsylvanian and to the Permian. These species can be further differentiated into two groups, which are possibly of generic or, at least subgeneric rank: in one belong *Acanthopecten meeki* Newell and *A. coloradoensis* Newell, and in the other two upper Permian species described by Girty and mentioned above.

ACANTHOPECTEN GRANDIS, n. sp.
Pl. 94, fig. 1,2;
Pl. 95, fig. 1–5

The species is larger than any previously known forms assigned to the genus either in its narrow or broad understanding. The left

valve has a typical pectinoid shape, that is, it is disk-like, and has a long straight hinge. Its posterior and anterior are equally well rounded and the wings are also subequal, though, as is usually for pectinoid shells, the anterior wing is differentiated by a deeper, narrower, more abrupt sinus than the acutely pointed posterior wing. The surface is ornamented by 19 strong radiating ribs, with no additional costae added in its ontogeny. Each rib is surmounted by a narrow sharp keel. The ribs are traversed by fine lines of growth, and by a few concentric lamellae, that produce the typical acanthopectoid dentate ventral margin, with a sharp spine between each pair of costae. However, the youngest dentate lamella appears at a distance of 13 mm. only or more from the apex, and subsequent lamellae develop at a somewhat irregular spacing from 2 to 5 mm. apart.

The hinge and faintly indicated resilifer in *Acanthopecten grandis* are quite typical for *Acanthopecten*, as demonstrated by Newell. The wings are ornamented by lines of growth only, which are here somewhat stronger than in the grooves between the costae.

The species resembles *Acanthopecten carboniferous* (Stevens) so much that there is hardly any doubt that it is its ancestor. Common are the general character of the shell, about the same number of radial ribs, and the same type of ornamentation. *A. grandis* differs from *A. carboniferous* in being larger, in having the lamellae developed only at the late mature stage, and in having three (or more) flattened spines in the lower part of the concavity of the posterior edge, while in *A. carboniferous* only one spine is developed at this place. Among all illustrated specimens of *A. carboniferous* the nearest to *A. grandis* is the left valve from Wewoka (Girty, 1915, pl. XVII, fig. 10, 10a).

In Table 2 are entered principal dimensions in mm. of *Acanthopecten carboniferous* and of *A. grandis*.

The evolutionary tendency from *Acanthopecten grandis* to *A. carboniferous* is expressed in reduction of overall size and development of dentate lamellae at earlier ontogenetical stages. In the examples of *A. carboniferous* from the upper Desmoinesian (Wewoka) the earliest dentate lamina is 11 mm. from the apex, while in the example from the Missourian Series (Westerville limestone, Newell, 1937, pl. 12, fig. 8) the first dentate lamina appears at 5.5 mm. from the apex.

Genus STREBLOCHONDRIA Newell

The shell of the genus is "ornamented with numerous radiating intercalcate costae on both valves, crossed by fine regular fila so that the surface has a regular latticed ornamentation" (Newell, 1937, p. 80), but in some species the lattice ornamentation becomes obsolete in the posterior and the middle of the shell, and in other "is preserved only at the umbones." In an enlarged photograph of *Streblochondria* (?) *tenuilineata* (Meek & Worthen) from the middle Pennsylvanian of Clinton County, Illinois (1937, pl. 15, fig. 14c) only regularly disposed concentric fila are shown. Newell states that *Streblochondria ? tenuilineata* "differs from typical *Streblochondria* in being mostly smooth.

STREBLOCHONDRIA (?) TENUILINEATA (Meek & Worthen)

Pl. 94, fig. 3,4;
Pl. 95, fig. 10,11

Pecten tenuilineatus MEEK & WORTHEN, 1860, Philadelphia Acad. Nat. Sci., Proc., p. 452.

Streblopteria ? tenuilineata MEEK & WORTHEN, 1866, Illinois Geol. Survey, vol. 2, p. 334, pl. 26, fig. 9a,b.

Crenipecten foerstii HERRICK, 1887, Denison Univ., Sci. Lab., Bull., vol. 2, p. 28, pl. 3, fig. 9,9a; MARK, 1922, Ohio Geol. Survey, Bull. 25, p. 230, pl. 13, fig. 7,8.

Streblopteria tenuilineata SAYRE, 1930, Kansas Geol. Survey, Bull. 17, p. 121, pl. 11, fig. 3,3a.

TABLE 2.—PRINCIPAL DIMENSIONS IN MM. OF *Acanthopecten carboniferous* AND *A. grandis*

Left Valves	Width	Height	Hinge	Convexity	Ribs	Age and Localities
A. carboniferous	19	17	?	3 or 4		M. Carb., Centralia, Ill.
A. carboniferous	15	16	12	?	16	Wewoka, Oklahoma
A. grandis	26	26	25	6	19	Redoak Hollow, Oklahoma

Three incomplete valves came from locality I, and one, consisting of outer and inner mold of a right valve, from locality III. Most important is one of the three valves from locality I, because in this left valve its substance is in greater part preserved, and details of its outer surface can be observed. Its surface ornamentation consists of the following. Very fine and regularly spaced (18 per 1 mm.) concentric lines cover all surface, in a few of these, at not very regular intervals, become more prominent, wrinkle-like. To these lines are added fine and narrow radiating costae only over umbonal part and along the lateral margins, below anterior and posterior auricles of left valve. In the middle part and along distal margin this valve is smooth, with only faint concentric lines, and very faint pits. Same pits cover the other parts of valve as well.

Inner molds of two left valves from locality I show well preserved narrow triangular cardinal area (hinge plate), which is covered with very faint longitudinal striae, and oblique narrow ridges, running from beak to the inner edge of hinge line, anterior ridge much shorter than posterior one.

Posterior auricle has semicircular outline and is differentiated from the body of valve by a deep depression. Anterior auricle is narrow, a mere flattening out of antero-ventral margin, and its margin continuous with gently convex anterior margin of the valve. The angle at which the edge of the auricle meets the edge of hinge line is slightly rounded.

Discussion.—Redoak Hollow specimens are essentially similar to *Streblochondria ? tenuilineata*, including the spacing of the concentric fila in the left valve, which is constant (18 per 1 mm.) over its whole surface.

Genus EUCHONDRIA Meek

EUCHONDRIA SUBQUADRATA, n. sp.

Pl. 94, fig. 5,6

Outer molds of two left valves of this species were recovered, the younger of the two being selected as holotype because of its completeness and perfect preservation of its sculpture throughout.

The type of external sculpture of these pectinoid valves is so much like that in *Euchondria levicula* Newell (1937, p. 107, pl. 1, fig. 6,7; pl. 19, fig. 5,10,11,18), that generic classification of the new species with *Euchondria* Meek seems quite safe. It is particularly close to that illustrated by Newell (pl. 19, fig. 11) which is also "an external mold (concave imprint) of a large left valve" from the Hushpuckney shale (lower Missourian Series) at Winterset, Iowa. In both *E. subquadrata*, n. sp., and *E. levicula* the sculpture consists of sharply outlined but low and narrow radiationg costae, whose number increases by intercalation. The wide spaces between the costae are slightly concave. Cancellate effect of the sculpture is created by the well developed and densely and regularly spaced lines of growth, some of which attain the prominence of the radiating costae. Following measurements were taken on the holotype of *E. subquadrata.*

Stronger concentric fila which tend to develop at more or less regular intervals, are spaced so that 5 to 6 of them may be counted per 2 mm. interval at a distance of 2½ to 4½ mm. from the beak in the holotype. There are 26 lines of growth per 1 mm. in the area at the same distance from the beak. About 7 costae are spaced in 1 mm. along the ventral edge at 4½ mm. distance from the beak. Newell (1937, p. 107) gives measurement only for the fila in *Euchondria levicula*, the interval between which is said to be "about .4 mm. across the median part of the shell and does not change appreciably across the adult part of the shell," a situation and measurement quite comparable to the same in *E. subquadrata*, n. sp.

The fundamental difference between the new species and *Euchondria levicula* lies in the outline of their left valves: it is pronouncedly oblique (prosocline) in the latter, while *E. subquadrata* is practically acline; besides, its anterior and posterior auricles (ears) are so nearly alike and so obscurely differentiated from the main part of the valve that a nearly quadrate outline is reached, hence its specific name: *E. subquadrata.* In this respect the form is reminiscent of some acline species of *Dunbarella*, and perhaps could belong to its ancestral stock rather than *Pterinopecten* Hall tentatively suggested as the ancestor of *Dunbarella* by Newell (1937, fig. 14, "Hypothetical phylogeny . . . entirely tentative and sub-

ject to revision," p. 36). Evolutionary development of *Euchondria levicula* from *E. subquadrata* consisted in greater differentiation of auricles accompanied by shortening of hinge and development of obliquity probably an indication of greater activity.

Genus PALEOLIMA Hind

In a comprehensive historical and analytical discussion of the genus *Lima* and its Paleozoic prototype *Paleolima* Girty (1915, p. 136–137) comes to the conclusion that the generic name *Lima* rather than *Paleolima* should be employed for the late Paleozoic bivalves of America. He states that, while the probabilities point to generic identity of the American and British Carboniferous *Lima* they also point to the generic identity of the British *Lima*, which constitute Hind's group of *Paleolima*, with the living genus (Girty, 1915, p. 137). Girty points out the absence of external ligament or subinternal resilium in *Paleolima*, though it is believed to exist by Hind, but actually has not been proved, and hence he feels justified to use the generic name *Lima* for the specimens from the Mississippian and Pennsylvanian of the Interior.

However, Hind's decision not to use the name *Lima* for the late Paleozoic shells as long as there remains doubt about the character and position of the ligaments in the shells of the fossils related to the living *Lima*, seems more nearly acceptable and is applied in the present paper. The rule, which is here consistently followed, is that the fossil invertebrates are referred to living genera only when the diagnostic generic characters of the latter are reasonably proved to exist in them.

TABLE 3. PRINCIPAL DIMENSIONS IN MM. OF *Paleolima*

Specimens	Length	Hinge	Height	Convexity	Age
P. inequicostata (type)	13.5	5.6	11	about 3	Late Morrow
P. inequicostata Mather	12	7.5	11	about 2.5	Redoak Hollow
L. retifera Morningstar	17.5	7	17.5		Pottsville
L. retifera Girty	15	6.5	15.5		Wewoka
P. simplex Phillips	20		20		L. Carboniferous

PALEOLIMA INEQUICOSTATA Mather

Pl. 92, fig. 13

Paleolima inequicostata MATHER, 1915, p. 229–230, pl. XV, fig. 18.

Although Mather's form from the Kessler limestone of Arkansas was described from a single somewhat incomplete inner cast of the left valve, its general shape, size and magnitude of radiating costae or ribs are so close to form from the Redoak Hollow that identity of the two seems certain. Mather emphasizes inequality of prominence of costae "growing successively fainter anteriorly," on the internal cast of left valve here described. There is also somewhat inequal spacing of the strong costae in the ventral

EXPLANATION OF PLATE 97

FIG. *1*—*Aviculopecten* sp. *C*. External mold of posterior (?) of right (?) valve ×10.

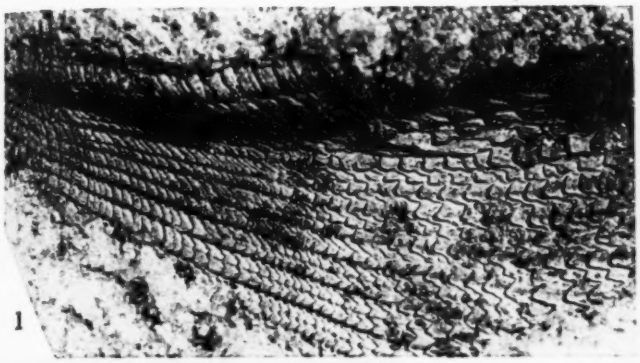
2–5—*Cypricardella* (?) *enigmatica*, n. sp. *2*, Outer mold of right valve (holotype), ×2; *3,4*, upper and lateral views of internal mold of left valve, ×2; and *5*, detail of outer surface of holotype, ×40.

6–8—*Eopleurophorus* cf. *P. spinulosa* (Morningstar). *6,7*, Internal and external mold of right valve, which is broken transversely into two subequal halves, ×2; and *8*, external mold of a posterior of another right valve, ×10.

9–11—*Eopleurophoras immaturus* (Herrick). *9*, Internal mold of complete left valve, ×1; *10*, external mold of nearly complete left valve, ×10; *11*, external mold of unusually short right valve, ×2.

12—Sanguinolites raleighensis Price. Incomplete external mold of left valve, ×2.

13—*Sanguinolites* sp. Small fragment of large shell, ×10.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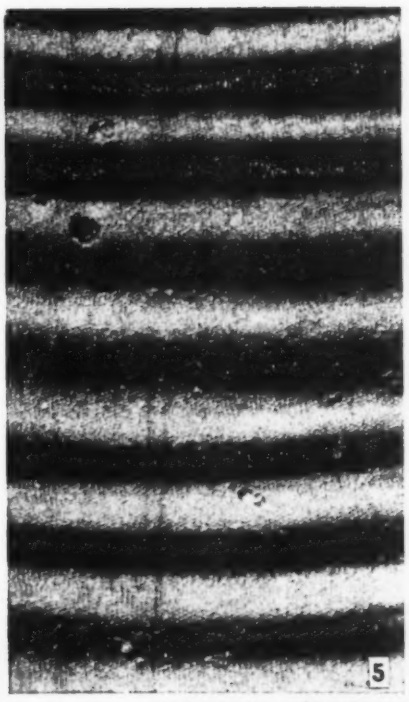
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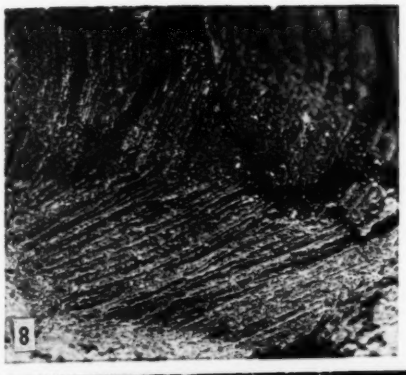
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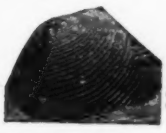
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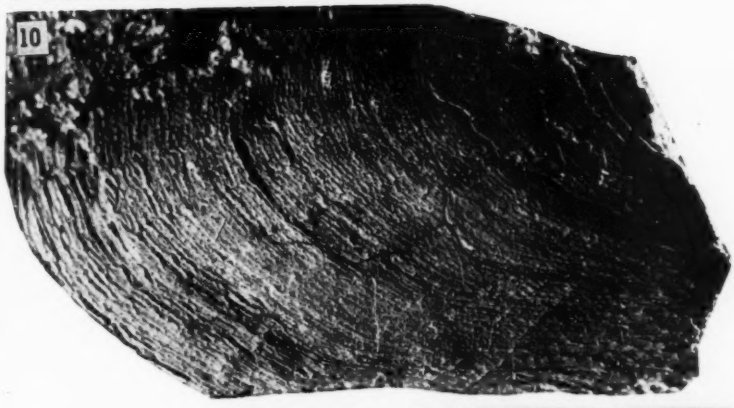
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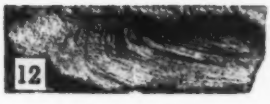
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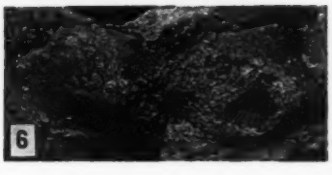
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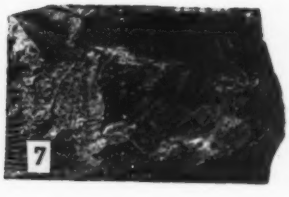
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part of the adult shell, which is incomplete in Mather's type. The species is undoubtedly related to *Lima retifera* Shumard, known to range from the Pottsville to upper Conemaugh of Ohio (Mark, 1911; Morningstar, 1922), and also described from the Wewoka of Oklahoma (Girty, 1915); but it differs from this species by greater obliquity and correspondingly smaller height, smaller size, and smaller number of radial ribs. The latter difference is not merely a consequence of smaller size of shell, because no new ribs seem to be added by intercalation or by bifurcation, in the mature part of shell. The number of ribs in *Lima retifera* is 23–24, as seen in its illustration (Morningstar, 1922, pl. XIII, fig. 10, reillustrated from Mark, 1911); and apparently the same number of ribs appears in the incompletely preserved shell illustrated by Girty (1915, pl. XVII, fig. 8), while in the form here described the number is only 18. Mather gives no information on the number of ribs, and they cannot be satisfactorily counted on the illustration of his incomplete shell, but their size and spacing on the preserved part of the shell seems to be sufficiently close to that in the specimen here described. The greater obliquity of *Paleolima inequicostata* may be described thus: the greatest convexity of its periphery is about opposite the end of its posterior wing, while the greatest convexity in *L. retifera* is opposite about the middle of the posterior wing, or closer to its beak. Size differences between two species are expressed in table 3 of their principal dimensions.

The only species of *Lima* or *Paleolima* known in the Chester, *L. chesterensis* Worthen (1890, p. 120–121, pl. XXII, fig. 7), is less oblique than either *P. inequicostata* or *P. retifera;* its height is substantially greater than its width; and its costae number from 28 to 30. *Paleolima minor* Weller from the St. Genevieve (1916, p. 251, pl. 16, fig. 12) is higher than wide and has shorter hinge.

More nearly similar to our *Paleolima inequicostata* is the British *P. simplex* (Phillips) as redescribed by Hind (1903, p. 39–40, pl. XIX, fig. 24–27), but the latter is a much larger form, 20 mm.×20 mm., being in this respect nearer to *L. retifera* described by Morningstar.

Family Coelonotidae M'Coy, 1855

Hind included in the family the genera *Tellinomorpha* and *Allorisma* (1900, p. 365) besides *Sanguinolites* and *Grammysia* placed in it by M'Coy. The four genera are so similar externally that it is difficult to classify in one or the other some species whose inner structure is unknown or incompletely known.

In the broad understanding of the genus *Grammysia* de Verneuil (1847) by Hall the genus *Sanguinolites* M'Coy (1855) becomes its junior synonym. However, the comprehensive *Grammysia* of Hall includes so many diverse species that he divided it into "four natural groups . . . for convenience of reference and description" (1885, p. XXXI). His fourth group, named "(Section d, elongata) *Grammysia communis,*" corresponds closely to *Sanguinolites* as understood by Hind (1900), whose understanding of *Sanguinolites* is here generally followed. It seems that Hind's 1900 critical review and conclusions on these genera have not been superseded by an equally complete later investigation, and thus should be generally accepted. His division of *Sanguinolites* into two groups, one represented by genotype *S. angustata* and "characterized by concentric ridges and sulcations," and the other represented by *S. tricostatus* and characterized by "smoother" exterior is also accepted, and for the "smoother group" a new generic name *Eopleurophorus* is introduced. Hind placed in his first group some species like *S. omalianus* which approach the genus *Grammysia* and which may be eventually transferred to *Grammysia* or segregated into another genus or subgenus.

Genus Sanguinolites M'Coy

Hind defines the shell of the genus as

> "transverse, oval; the ends rounded, the posterior deeper in the dorso-ventral diameter than the anterior; very inequilateral, compressed, strongly carinate, with a much-compressed and hollowed dorsal slope, often crossed by one or more radiating lines or ridges. Lunule and escutcheon large, the latter bound externally by an erect, curved ridge. . . . The surface is ornamented with parallel concentric ribs or lines, which, as a rule, pass into striae on the posterior slope. Surface tuberculate (1900, p. 362).

One of the most obvious differences from the related genus *Allorisma* is the carination, that is the presence of an oblique ridge.

Several specimens from the Redoak Hollow are referred to the genus tentatively, mostly on the resemblance of the exterior to some species classified with *Sanguinolites*.

SANGUINOLITES OMALIANUS
(de Koninck)
Pl. 96, fig. 1

Pholadomia omaliana DE KONINCK, 1842, Anim. Foss. Terr. Carb. Belge, p. 65, pl. V, fig. 4.
Allorisma omaliana BIGSBY, 1878, Thesaurus Devonico-Carboniferus, p. 295.
Sanguinolites omalianus HIND, 1900, Paleont. Soc., vol. LIV, Brit. Carb. Lamell, pt. V, p. 372–374, pl. XL, fig. 17–24.

The single internal mold is impressed in fine-grained sandstone. It is referred to the genus *Sanguinolites* on account of its close resemblance to the medium size examples of *Sanguinolites omalianus* from the Lower Carboniferous of the British Isles, as illustrated by Hind (1900, pl. XL, figs. 18 and 24; 24a in particular). The resemblance is not merely in size and shape, but also in the proportional distance of the beak from the anterior margin, and in the magnitude of "concentric grooves and ribs," as the sculpture is described by Hind. Presence of very gentle sinus in the middle of the shell in the specimen from the Redoak Hollow is also an important specific character that corresponds to the same in *Sanguinolites omalianus*. It seems that the combination of just mentioned structural similarities is not a mere coincidence, and the form from the Redoak Hollow is truly closely related to, if not identical with de Koninck's species. Comparative measurements of those shells which were illustrated by Hind, and which are nearest in size to the unique valve from the Redoak Hollow (Table 4 of measurements below), also indicate the close proximity between these forms. Only the convexity of the valves from the British Isles is proportionally greater, but this character has been observed on a larger individual than that from the Redoak Hollow, and perhaps the convexity of the shell in *S. omalianus* becomes proportionally much greater with its growth.

The present generic assignment of the species from the Redoak Hollow is considered provisional on account of considerable difficulty involved in differentiation between *Sanguinolites* and *Allorisma*, especially in the case of the discussed species. In formation of the difference between these genera Hind placed above all the presence in *Sanguinolites* of an "oblique ridge," which is purportedly absent in *Allorisma;* and furthermore on the presence in the latter genus of a "peculiar character of the anterior margin, which seems to be continuous with the outer edge of the umbo" (Hind, 1900, p. 365). However, it seems that in the above cited medium size examples of *S. omalianus* illustrated by Hind (1900, pl. XL, fig. 18 and 24,24a) the oblique ridge is rather insignificant, but so it is also in the example from the Redoak Hollow.

In table 4 are entered the principal measurements of the British and American species.

None of the numerous known American Mississippian or Pennsylvanian species of *Allorisma* seems to be anywhere near the form from the Redoak Hollow.

SANGUINOLITES RALEIGHENSIS Price
Pl. 97, fig. 10

Sanguinolites raleighensis PRICE, 1916, West Virginia Geol. Survey, County Reports, Riley County . . . , part IV, p. 707–708, pl. XXX, fig. 12–13.

The single incomplete external mold of left valve from the Redoak Hollow agrees so

TABLE 4.—COMPARATIVE MEASUREMENTS IN MM. OF *Sanguinolites omalianus*

Source of Material	Illustrations	Width	Height	Convexity	Peak from anterior
Redoak Hollow, Oklahoma	Present pl. 28, fig. 1	18	11	3.5	5
L. Carboniferous	Hind, 1900, pl. XL, fig. 8	20	13.5	?	4.5
of British Isles	Hind, 1900, pl. XL, fig. 24,24a	28	19.5	10	8

closely with the external mold of the single (left) valve illustrated by Price that identification with it seems certain. The size is practically the same, Price's dimensions being 16×7 mm., while the restored size of the valve from the Redoak Hollow seems close to 21 or 22×8 mm. Most characteristic are the dorso-posterior radiating costae: one very close to the posterior part of the hinge, two next spaced much wider apart, and a much fainter fourth costa, spaced slightly closer and running from the postero-ventral corner only half-way to the beak. All these costae can be detected on a specimen from the Redoak Hollow, even if not as distinct as in the type of the species.

To Price's detailed description of the species can be added only one observation based on the specimen from the Redoak Hollow: the earlier lines of growth outline a valve which appears much more transverse than the adult shell of the species—but this does not seem to be the case in the type illustrated by Price.

Classification of the species with the genus *Sanguinolites* seems fully justified, particularly because in its shape and sculpture it is very similar to *Sanguinolites tricostata* (Portlock), and also to the related *S. stratogranulatus* Hind, both from the Lower Carboniferous of British Isles (Hind, 1900, pl. XLII, fig. 11–15, 16–22). Perhaps the only difference of these British forms from *S. raleighensis* is that the latter are about twice as large as the former.

SANGUINOLITES sp. *D*
Pl. 96, fig. 11;
Text-fig. 1—16,17

The small single valve with broken off beak, has its sub-central position indicated by the radially converging rows of fine punctae and the concentric ribs.

Valve elongately oval, narrower anteriorly, truncated posteriorly, 8 mm. wide, 5½ mm. high, and 1¾ mm. thick. Beak apparently above the nearly straight hinge. Gentle but distinct constriction slightly anterior to the center of ventral edge, reflected in the concentric sculpture.

Prominent wave-like concentric sculpture is superposed over much finer growth lines, which become diagonal to the concentric ridges in the posterior. Radiating rows of punctae, 10 per 1 mm. at the venter, undulate gently and harmoniously with the rise and fall of the concentric waves. Only growth lines, but not concentric waves and rows of punctae, cover the postero-dorsal area, which is delimited by a gentle ridge and traversed by two equally gentle ridges.

Discussion.—The unusual for *Sanguinolites* sub-central position of beak could be ascribed to young age of the valve, rather than considered its specific characteristic. However, *Sanguinolites ovalis* Hind (1900), p. 411, pl. 46, fig. 14–17), which is nearest to it in shape and sculpture, has its beak much closer to the anterior even in the young stages comparable in size to the Redoak Hollow valve.

SANGUINOLITES (?) sp. *E*
Pl. 91, fig. 13,14

The single valve with broken off beak is traversed diagonally by umbonal angularity that divides it into subequal halves. Ventral half is smaller, nearly flat, and covered with straight lines of growth. Dorsal half is traversed by a gentle medial ridge, and is concave between it and the diagonal angularity. Growth lines change direction at medial ridge, curve sharply toward posterior at dorsal edge.

Diagonal angularity coincides with a narrow groove and sharp turn of growth-lines, the angle of turn attenuated posteriorly to 60–65°.

Discussion.—The form could be classified with *Goniophora*, but the gentle concavity of its dorsal slope crossed by "radiating lines" places it closer to *Sanguinolites*. Grooved diagonal angularity is unlike that in all species of *Goniophora* or *Sanguinolites*. Nearest to the Redoak Hollow form is *S. striatolamellosus* de Koninck (Hind, 1900, p. 398, pl. 43, fig. 5,8–11), but its diagonal angularity is not attenuated posteriorly and not accompanied by a groove.

Genus ALLORISMA King
ALLORISMA MAYNARDWHITEI, n. sp.
Pl. 96, fig. 2–5

The single right valve, which serves as the type of the new species, is a practically complete internal mold. In addition, there is a part of an external mold of the same valve that is sufficiently large and well preserved

to show the minute details of a very characteristic ornamentation. This ornamentation consists of very faint and densely spaced growth lines, over which are superimposed somewhat less regularly concentric, but more elevated and more distantly spaced (about 6 or 7 per 1 mm.) fila. Faint radial costae cross the fila at a more or less acute angle, and at many but not all points of their crossing arise minute tubercles. At some places a few tubercles follow each other at equal intervals along sub-concentric to concentric lines, but only rarely such groups of tubercles continue to do so for a distance larger than 1 mm. Besides the just described sculpture there are also still coarser concentric undulations, that average about 3 to 4 per 4 mm. in the area from 8 to 12 mm. distance from the beak; they become gradually more densely spaced in the areas toward the beak. On the other hand, at the distance farther than 12 mm. from the beak these undulations flatten out and tend to become shingle-like. The internal surface of the valve reflects the roughest concentric sculpture of the exterior, but otherwise is smooth.

Discussion.—Three genera: *Sanguinolites*, *Allorisma*, and *Tellinomorpha* have in common the outline of the shell, anterior position of the moderately prominent beak and some species in each genus possess also a sculpture much like the one just described, including the rows of tubercles. The presence of the latter detail was recorded by Hind (1900) only in a few species: *Sanguinolites striatogranulosus* (Hind, 1900, pl. XLII, fig. 20a), *Allorisma sulcata* (ibid., pl. XLVIII, fig. 7a), *A. ansticei* (ibid., pl. XLIX, fig. 1a) and *Tellinomorpha cuneiformis* (ibid., pl. XLIX, fig. 6a); however, the form from the Redoak Hollow is identical with none of these. The presence of tubercles upon the shell surface is clearly of no generic significance, and the species from the Redoak Hollow is here classified with genus *Allorisma* not for this but for the following reasons: it contains no distinct umbonal ridge, the presence of which, according to Hind (1900, p. 365), separates the genus *Sanguinolites* from *Allorisma;* and its hinge is edentulous, which makes it unlike that of *Tellinomorpha*, which has a cardinal tooth. The species from the Redoak Hollow is in many respects like *Allorisma sulcata* (Flemming) but differs from it by its higher beak and less anterior position of the same. Otherwise, it is very close to the latter species, and may be considered its direct descendent. In Table 5 the principal dimensions of *Allorisma maynardwhitei* may be compared with those of the nearest to it, individuals of *A. sulcata*, which are illustrated by Hind.

None of the previously described species of *Allorisma* from either Mississippian or Pennsylvanian of America possess tuberculated shell surface; and they are less similar to *A. maynardwhitei* in this and other respects, than *A. sulcata* from the Lower Carboniferous of Europe.

ALLORISMA SNIDERI, n. sp.
Pl. 93, fig. 6,7

Allorisma walkeri SNIDER (part), 1915, Oklahoma Geol. Survey, Bull., no. 24, p. 114, pl. VII, fig. 4 (not fig. 5).

The new species of *Allorisma* from the Redoak Hollow belong to the group of *Allorisma matheri-Allorisma maxvillensis*, which includes small to moderate sized species of the genus, and are common in and characteristic of the upper Mississippian. When Girty identified a species from the Batesville of Arkansas with *A. maxvillensis* (Girty, 1915, p. 108, pl. X, fig. 4,5), he ad-

TABLE 5.—PRINCIPAL DIMENSIONS IN MM. OF *Allorisma sulcata* GROUP

Species	Source of mat.	Illustrations	Width	Height	Convexity	Beak from anterior
A. maynardwhitei	Redoak Hollow	Present pl., fig.	33	18.5	7.5	10
A. sulcata (Fleming)	Lower Carb. of Brit. Isles	Hind, 1900, pl. XLVII fig. 8	62	30	22	11
		Hind, 1900, pl. XLVII, fig. 4	34	17	?	7
		Hind, 1900, pl. XLVII, fig. 9	24	12	?	6

mitted that "one of the specimens is perhaps not quite as transverse as typical *maxvillense*," but believed that other characters are sufficiently close to justify the identification, at least until contradictory evidence comes to light. Girty did not measure his specimens, but his fine photographs allow us to do so; the measurement now taken on them (see table of measurements below) shows that both of his illustrated specimens differ from *A. maxvillensis* Whitfield by being "less transverse." Their length is less than two times the height, while in the types of the species illustrated by Whitfield (1889, pl. XIV, fig. 7,8) all valves are more than twice as long as high. Besides, the beaks in *A. maxvillensis* are less than $\frac{1}{3}$ of the total length from the anterior edge, while in the form from the Batesville the beak is only between $\frac{1}{4}$ and $\frac{1}{5}$ of the total length from the anterior. Also, the beak in the latter is more elevated above the dorsal edge. In view of this, Girty's form is now considered a new species and is designated as *Allorisma girtyi* Elias, n. sp. The largest of the two specimens illustrated by Girty (1915, pl. X, fig. 5) is selected for its holotype.

Snider identifies with *Allorisma walkeri* Weller a number of shells of this genus from the Chester group in Oklahoma, but he admits that the originals of the species from the Batesville "are possibly a little more transverse than the Oklahoma specimens." However, he also did not measure his fossil. Only one of his illustrated specimens is sufficiently complete for the purpose of comparison (Snider, 1915, pl. 7, fig. 4), and this individual is in all respects much like the specimens from the Redoak Hollow, for which a new name *A. snideri* is here introduced. The new species is characterized by being comparatively short, its length being less than twice its height, just as in *A. girtyi*, but it differs from the latter in having the beak very far from the anterior edge, more than $\frac{1}{3}$ of the total length of the shell. In *A. girtyi* this distance is less than $\frac{1}{4}$ of the total length of the shell. As to *A. walkeri* the new species *A. snideri* differs in smaller size, a length less than twice the height, and the position of the beak far from anterior, as just mentioned.

The dimensions of the group of the species discussed are summarized on the following table. Four species in the table are from the Chester group, while only one, *Allorisma snideri* was collected in the Redoak Hollow. Mather did not collect any species of *Allorisma* from the upper Morrow of Arkansas, and neither does Girty record any from the Morrow of the Ardmore Basin, except some shells very high in the Dornick Hills group: in the Pumpkin Creek or Lester, where he identifies *Allorisma terminale* (Tomlinson, 1929, p. 73).

Genus TELLINOMORPHA de Koninck

TELLINOMORPHA SCHENCKI, n. sp.

Pl. 93, fig. 8; Text-fig. 1–14

The single specimen on which this species is based is an internal mold of a right valve, which is wider than high, has an anteriorly placed beak, and reflects concentric undulations of the outer sculpture; these are characters which are typical for the three closely related genera: *Sanguinolites*, *Allorisma*, and *Tellinomorpha*. A single (scoop-like) tooth in the valve distinguishes *Tellinomorpha* from the other two genera of the group. Although a number of examples of a few species of the genus have been previously described, many from the Lower Carboniferous of the British Isles and some from the Upper Carboniferous of Belgium, the dentition has been observed only once, on a right valve of *Telinomorpha cuneiformis* de Koninck (1885, p. 91, pl. XXI, fig. 1,2) which serves as the type of the species and as the genotype (redescribed and reillustrated by Hind, 1900, p. 430, pl. XLIX, fig. 5–9). In the right valve of the type the tooth is described as being flanked by sockets on either side, but in the right valve from the Redoak Hollow there is only a socket posterior to the tooth, while no clearly indicated socket on its anterior side can be detected. Unfortunately, no illustration of the tooth in the valve serving as the type of the species and the genus has been published, and therefore it is impossible to ascertain how serious is this morphology discrepancy. It seems that it is not of great taxonomic significance, because other important characters give further support to the generic classification of the valve from the Redoak Hollow: its posterior end is pronouncedly gaping, and its internal surface (as seen in the internal mold) is covered with both concentric undulations and very faint radial lines in the

anterior and the middle part of the shell. In these and all other morphological characters the valve from the Redoak Hollow resembles closely *Tellinomorpha cuneiformis* de Koninck as illustrated by Hind (1900, pl. XLIX, fig. 5–9); it differs from the latter only in the absence of medial sinus and in a somewhat higher elevation of the beak above the hinge line. *T. schencki* is also smaller than the smallest individuals among those illustrated by Hind. In table 6 are entered the principal dimensions of *T. schencki* and *T. cuneiformis*.

T. schencki is the first record of the genus in America. In the Old World it is known from the Lower Carboniferous of the British Isles and the Upper Carboniferous of Belgium.

TABLE 6.—PRINCIPAL DIMENSIONS IN MM. OF *Tellinomorpha cuneiformis* GROUP

T. schencki, n. sp.	Readoak Hollow	Original	23	16	4.5	8
T. cuneiformis	Lower Carboniferous	Hind, 1900, pl. XLIX, fig. 5	31	18	7.5	9
T. cuneiformis	Lower Carboniferous	Hind, 1900, pl. XLIX, fig. 7	64	30	?	20

Genus EOPLEUROPHORUS, new genus

Sanguinclites tricostatus HIND, 1900, Palaeontographical Society, vol. 54, p. 366.
Pleurophorus MORNINGSTAR, 1922, Ohio Geol. Survey, 4th Ser., Bull. 25, p. 236–241.

The common Permian genus *Pleurophorus* King (1844) differs from the discussed genera of the family Coelonotidae in having a cardinal tooth in each valve (Böhm, 1914, p. 555; Newell, 1940, p. 297) and buttress-like ridge behind anterior adductor scar. *Pleurophorus* is placed by Dall (1913) in order Anomalodesmacea while Coelonotidae are placed in order Prionodesmacea, in spite of the fact that the smoother of the two groups of *Sanguinolites*, typified by *S. tricostatus* "has all the external characters of *Pleurophorus*" (Hind, 1900, p. 366). The presence of a ridge behind anterior adductor in *Sanguinolites* adds to this similarity, and it seems possible that the cardinal tooth of the genus *Pleurophorus* developed in late Pennsylvanian or early Permian time from a smoother group of *Sanguinolites*. Meek & Worthen's detailed description of the exterior of the American shells classified in *Pleurophorus* (1865, 1866) contains no description of cardinal tooth in either upper Pennsylvanian or lower Permian species, and they state that in *P. subcostatus* cardinal teeth are unknown (1866, p. 348). In spite of having internal molds at his disposal, Girty found no cardinal teeth in the Texas Upper Permian species referred by him to *Pleurophorus* and the related genus *Myoconcha* (1908, p. 444, 446–447), but Newell discovered cardinal tooth in both valves of *Pleurophorus albequus* Beede from the Whitehorse sandstone (1940, p. 297), at the top of the upper Permian in the northern Mid-Continent of America. Newell doubts that Licharev's (Likharev) genus *Pleurophorina* differs from *Pleurophorus* in having no cardinal tooth in left valve, as Licharev's photographs of squeezes do not illustrate this feature convincingly (1940, p. 298). However, if Licharev's observation is correct, *Pleurophorina* could be regarded as transitional stage in the development of *Pleurophorus* from *Sanguinolites*.

Newell makes no attempt at generic reclassification of the lower Pennsylvanian *Pleurophorus immaturus* Herrick and *P. spinulosus* Morningstar, but points out the presence in them of the radiating lines of papillae (illustrated by Morningstar, 1922) similar to the same described by Licharev in *Pleurophorina;* and illustrates the presence of the same kind of radiating papillae in *Pleurophorus albequus longus* Beede (Newell, 1908, pl. 3, fig. 16).

Because cardinal tooth is apparently absent in the American upper Mississippian, Pennsylvanian and some Permian species customarily placed in genus *Pleurophorus*, they deserve to be segregated into a genus distinct from *Pleurophorus*. The genus *Pleurophorella* was introduced by Girty for the American *Allorisma*-like forms that differ by "more sharply defined and more strongly depressed lunele, and the presence of costae, the development of which results in a truncation of the posterior outline" (1904, p. 728). The genotype *Pleurophorella papillosa* Girty, and the provisional inclusion by Girty in *Pleurophorella* of *Pleurophorus angulatus* Meek & Worthen, *P. tropi-*

dophorus Meek, and *P. occidentalis* Meek & Hayden, makes *Pleurophorella* a Pennsylvanian and Permian genus. The genus *Sphenotus* Hall (1885, p. XXXIII) is externally similar to *Pleurophorella* Girty and probably is its senior synonym, if Hind's expressed doubt about *Sphenotus* having cardinal teeth, mentioned in its characteristics but not shown in a single illustration by Hall, will prove to be justified. Morningstar differentiates *Pleurophorella* (=? *Sphenotus*) from the Pottsville forms which lack posterior truncation and places in *Pleurophorus: P. tropidophorus* Meek, *P. immaturus* Herrick, *P. oblongus* Meek, and *P. spinulosa* Morningstar. It seems that some British Carboniferous form, such as *Sanguinolites striato-lamellosus* (de Koninck) can be placed in *Pleurophorella* (=? *Sphenotus*), but the group typified by *Sanguinolites tricostatus* (Portlock) (Hind, 1900) would certainly embrace the forms placed by Morningstar in *Pleurophorus*. New genus *Eopleurophorus* is here proposed for this group, and *Cypricardia ? tricostata* Portlock, 1843, as interpreted by Hind (1900, p. 391) is designated its type species.

Generic characteristics.—Conch sub-oval, wider than high with rounded anterior and posterior; beak subdued, placed close to anterior; anterior sculpture consists of growth lines and concentric plications, which become inconspicuous in the middle and the posterior; dorso-posterior ornamented by three or more inconspicuous radiating ridges, marked by angular changes in the direction of straight growth lines; surface covered by radiating rows of fine papillae; hinge probably edentulous in all species, certainly in some; pallial line entire; anterior adductor scar close to beak, bounded behind by a ridge.

Differs from *Sanguinolites* in restricted sense or group of *S. angustatus* (Hind, 1900, p. 366) by less conspicuous sculpture and the absence of concentric plications in the postero-dorsal area, which is covered by growth lines with angular turn at radiating ridges; differs from *Pleurophorella* and *Sphenotus* by the absence of posterior truncation and of the conspicuous diagonal ridge that borders postero-dorsal area in *Pleurophorella* and *Sphenotus;* differs from *Pleurophorus* by having no cardinal tooth.

The name *Pleurophorus* is preoccupied by Mulsant (1842) for a coleopterid insect, which necessitates new name for *Pleurophorus* King (1844), unless Likharev's *Pleurophorina* takes its place, embracing not only the shells with cardinal tooth in right valve only, as observed by Likharev (1925, p. 125) on its genotype from the Kazanian in the upper Permian of Russia, but also the shells with cardinal tooth in both valves, as typical for the upper Permian *Pleurophorus* of Western Europe, England, and America.

EOPLEUROPHORUS cf. E. SPINULOSA (Morningstar)
Pl. 97, fig. 6,11,12

Pleurophorus spinulosa MORNINGSTAR, 1922, Ohio Geol. Survey, 4th Ser., Bull. 25, p. 239–240, pl. XIV, fig. 9–11.

Only the posterior half of an adult left valve, and posterior end of a young left valve have been found, but these are so near to *Eopleurophorus spinulosa* that it seems that they can be referred to it provisionally; it is possible that when more nearly complete specimens are found they will reveal some differences from Morningstar's species worthy of a varietal and even specific differentiation.

The form from the Redoak Hollow has only four radiating costae in the postero-dorsal part, an important specific character that differentiates *Eopleurophorus spinulosa* from *E. immaturus* Herrick; and it has some scattered spines, the coarseness of which is also suggestive of *E. spinulosa*. However, in size it is intermediate between the latter and *E. immaturus*. Judging by the height of the posterior of the form from the Redoak Hollow (14 mm.) and its restored length, it is from $\frac{3}{5}$ to $\frac{3}{4}$ the size of *E. spinulosum*, and perhaps only about $1\frac{1}{4}$ times as large as *E. immaturus*. It is only slightly larger than the right valve of *E. immaturus* with "radiating markings evanescent," as illustrated on pl. XIV, fig. 7 by Morningstar (1922). Morningstar collected both *E. immaturus* and *E. spinulosa* from the Lower Mercer limestone, but found the former also in the McArthur limestone, that is higher in the Pottsville. Finding of *E.* cf. *spinulosa* in the Redoak Hollow is in harmony with the somewhat lower position of the species with four posterior ridges in the Pottsville of Ohio.

Sayre (1930) describes from the Drum limestone (Missourian Series) of Kansas and Missouri, a form which he believes identical with *Pleurophorus subcostatus* Meek & Worthen (1896, pl. 27, fig. 2,2a) from Illinois, but of slightly larger size. He describes "three faint radiating costae" in its postero dorsal region, but on one of his photographs (Sayre, 1930, pl. XII, fig. 13) there is, in addition, a fourth (lowest) costa, slightly weaker than the other three. This specimen, though much smaller than the mature shell illustrated on figure 12 of same plate, has nevertheless much coarser costae than the latter. Meek & Worthen (1866, p. 348) mention "traces of about three equal obscure radiating costae" on the postero-dorsal region of the internal cast of their type of *P. subcostatus*. They naturally could not observe the finer details of sculpture of the conch, and Sayre's material supplies this information. He finds that the surface, besides the mentioned radiating ridges, is covered with "fine concentric lines of growth," but does not mention any spines on it.

EOPLEUROPHORUS IMMATURUS (Herrick)
Pl. 97, fig. 6–8

Pleurophorus subcostatus? HERRICK, 1887, Bull. Denison Univ., vol. 2, p. 35, pl. 4, fig. 16,16a.
Pleurophorus immaturus HERRICK, 1887, Bull. Denison Univ., vol. 2, p. 145, pl. 14, fig. 17; MORNINGSTAR, 1922, Ohio Geol. Survey, 4th Ser., Bull. 25, p. 236–238, pl. XIV, fig. 5–8.

The status of *Eopleurophorus immaturus* was thoroughly revised by Miss Morningstar, who also established considerable variability of the species from the Pottsville of Ohio. She finds that the shells questionably referred by Herick to *Pleurophorus subcostatus* are not identical with the latter species, and on the other hand they are mature examples of the small shell which Herrick named *P. immaturus*. The broader concept of the species, as she interprets it, and as can be judged by a number of published illustrations (see the synonymy), make possible to identify with *E. immaturus* the specimens recovered from the Redoak Hollow with confidence.

Our specimen is a complete internal mold of a left valve, and nearly complete (without dorsal edge) external mold of the same. It is 15.5 mm. long, 7 mm. high, and its convexity is 2.5 mm. It is intermediate between the specimens illustrated on pl. IV, fig. 16a (Herrick, 1887) and on pl. IV, fig. 16 and (Morningstar, 1922) pl. XIV, fig. 6,7.

Hinge is straight, about $\frac{3}{4}$ the maximum length of the shell; stiffened by a linear thickening along the edge. Beak is only 1 mm. behind the anterior edge, incurved, pointing inward and forward, lower than the hinge. Antero-dorsal edge straight, at an obtuse angle to the hinge, but rounds gently into the hinge above and rather sharply into the anteroventral angle below. Ventral edge generally convex, but nearly straight for about half the length of the shell anteriorly, and at an angle of 15°–20° to the hinge. Posterior edge is broadly rounded, and obliquely truncated near its junction with the hinge.

The surface is covered completely with fine, densely spaced lines of growth, some of which are stronger and imbricate. The stronger lines become slightly stronger still in the anterior $\frac{1}{3}$ of the shell, toward which the lines display confluence. In this part are also developed spicules, which are arranged in densely spaced radiating and concentric rows; this kind of sculpture is considered by Morningstar most important for identification of the species, and for the first time discovered (in this species and *P. spinosa*) by her for the genus *Pleurophorus*. In the rear $\frac{2}{3}$ (where the spines are not developed) the valve is crossed by 7 or 8, more or less equidistantly spaced, low and narrow, and slightly wavering radiating costae. The concentric lines of growth, instead of curving gently, run a polygonal course, changing direction at an angle when interrupted by the radial costae. These costae become fainter, when approaching the beak, and fade out before reaching it. The costae ending in the middle of the ventral edge fade out at a distance from the beak.

Excellent preservation of the hinge and umbo in the external mold allowed the following observations previously unknown for the species and the genus. The straight posterior part of the hinge becomes very gradually thicker and narrower and also begins to curve gently as it approaches the beak; it curves more sharply directly under the beak, and then runs nearly straight at about 120–125° to the hinge line. It borders a narrow triangular escutcheon in front of the beak; under this escutcheon, in the depression of

the shell, lies strongly impressed anterior muscle scar; it is elongated along the hinge and situated very close to it. A long, narrow, straight elevation starts from the beak on the inner of the valve and runs in front of it, but in postero-ventral direction, for about ⅔ the distance to the venter.

ASTARTELLA (?) aff. A. CONCENTRICA (Conrad)
Pl. 96, fig. 6

Nuculites concentricus CONRAD, 1842, Acad. Nat. Sci. Philadelphia, Jour. vol. 8, pt. 2, p. 248.
Astartella concentrica GIRTY, 1915, U. S. Geol. Survey, Bull. 544, p. 142–144, pl. XVIII, fig. 2–9.

The single, not quite complete external mold of a left (?) valve seems closer to *Astartella concentrica*, as illustrated by Girty, than to the rest of the few known species of this exclusive Pennsylvanian genus. The generic assignment of the form from the Redoak Hollow is based on its beautifully preserved ornamentation: the surface is sculptured by not quite regularly spaced concentric lamellae, the flat interspaces between which are marked by numerous fine lines of growth. Besides, in the medial part of the valve these interspaces are also sculptured by numerous closely spaced radial prominences of very variable strength. By comparison, only *A. concentrica* illustrated and described by Girty, possesses this combination of sculptural features, even though the radial prominences illustrated by Girty (1915, pl. XVIII, fig. 9) are more regular in character and spacing than those in the form from the Redoak Hollow. On the other hand, the other features of the sculpture are remarkably similar: the sublinear lamellae in the earliest, apical part of the valve, changing rapidly to the broadly curved and slightly more diffusely spaced lamellae in the principal part of the valve, and back again to slightly more closely spaced lamellae in its submarginal part. Similar is also the peculiar slight irregularity of the width of the interspaces, and the dying out of some lamellae.

The indications that the form from the Redoak Hollow may belong to a new species is the broadly rounded outline of the anterior, and a denser average spacing of the lamellae. However, it seems prudent to defer final specific designation of the form until more nearly complete material is collected.

Following are the principal dimensions of the form: width probably about 8 mm. (restored); height 6.5 mm.; distance of apex from anterior margin abt. 3 mm.; number of concentric laminae 17, in average 3 laminae per 1 mm. except the middle area where there are 2 laminae per 1 mm.

The present form is the stratigraphically lowest recorded in America.

Genus CYPRICARDELLA Hall

Considerable confusion exists in the use of the generic name *Microdon* Conrad which is a synonym of *Cypricardella* Hall and has priority over it. However, the generic name *Microdon* has been introduced several times for various animals, and its first application was by Agassiz for a genus of fish in 1833. Hence, Conrad's name is invalid and Hall's name *Cypricardella* is now being accepted in preference to *Microdon;* but in the earlier publications, including those by Hall himself, the name *Microdon* is usually used. Hind gives a complete synonymy (1899, p. 345–346).

CYPRICARDELLA (?) ENIGMATICA, n. sp.
Pl. 97, fig. 2–5

Following description is based largely on the most nearly complete left valve, as represented by its external and internal mold. The valve is 12.5 mm. wide, 11 mm. high, and 4.5 mm. in convexity. The outline of the shell is sub-oval, but with an angular postero-ventral end. At this end terminates the umbonal ridge which extends to here from the beak, which is located at a distance about ⅔ of the width of the valve from its anterior. Hinge is short and gently curving; and just below the beak, which rises only slightly above the hinge, there is a short single tooth, anterior to which is a slight indication of a socket, probably to accommodate a tooth from the right valve.

Ornamentation consists of very regular concentric fila, with equally subangular crests and troughs, while there are no traces of ordinary lines of growth. On the other hand, when viewed under very high magnification, the surface of the conch shows very fine and regular granulation, the granules forming more distinct radiating, and less

distinct diagonal rows. When viewed under moderate magnification (of hand-lens) the surface appears smooth with a faint satin-like lustre. Above the umbonal ridge the concentric undulations show distinct confluence toward the antero-dorsal part, where they end in a short anterior part of the hinge. There seem to be no distinct lunule or escutcheon.

The additional two fragments of the external molds lack dorsal parts (broken off accidentally), but on the other hand these incomplete specimens have the above described fine satin-like texture most beautifully preserved, while the complete valve, selected as holotype, lacks this perfection of preservation of its surface. Measurements of the subangular undulations indicate 3 per 1 mm. in the younger part of the conch, at a distance from 2 to 7 mm. from the beak, and 2 per 1 mm. in the mature part, at a distance from 7 to 11 mm. from the beak.

Discussion.—This is one of the most puzzling among the pelecypods from the Redoak Hollow and it is only provisionally placed here in the genus *Cypricardella* Hall.

It seems that the combination of the satin-like smooth texture and the undulating concentric sculpture of the conch has not been recorded for the late Paleozoic pelecypods, but on the other hand the above described fine satin-like texture could have been either insufficiently well preserved, or merely overlooked, while actually it may be associated with what has been described, for instance, as "regular, fine concentric elevated lines which are equal to the spaces between" (Hall, 1858, p. 17) in *Cypricardella subelliptica* from the Salem (Spergen) limestone of Indiana, which resembles *Cypricardella* (?) *enigmatica.* Similar is also the form from the Batesville sandstone of Arkansas, also doubtfully referred to *Cypricardella* by Girty (1915, p. 110), who states (but does not illustrate) that its surface is "marked by more or less strong coarse, regular concentric striae." The magnitude of the concentric sculpture, as illustrated, for instance, on the natural size sketch of "a very large valve" of *Cypricardella oblonga* (*Microdon oblongus*) in Beede 1906, pl. XXIII, fig. 34, also seems quite comparable to that of the concentric sculpture in *C.* ? *enigmatica* from the Redoak Hollow. Another feature in common between these two species is a sharp bend of the sculpture along a line that can be termed umbonal ridge, though it is merely described as a "gibbous or sub-angular" slope by Hall (1858, p. 18, in *C. oblonga*). On the other hand, there exist some morphologic discrepancies between the structure of *C.* (?) *enigmatica* and that of the known species of *Cypricardella,* which make the assignment of the form from the Redoak Hollow to *Cypricardella* somewhat doubtful. Thus, its hinge is much shorter than that in *C. oblonga,* being proportionally only ⅓ as long as in the latter species. Its anterior edge in front of the beak is gently convex, while in *C. oblonga* and nearly all other Mississippian species of genus *Cypricardella* it is gently concave. *C.* (?) *enigmatica* shows no evidence of lunule or escutcheon which are developed in *Cypricardella,* but these are narrow and insignificant in *C. oblonga* and *C. subelliptica;* indeed, they could have naturally almost disappeared with the shortening of the hinge in *C.* (?) *enigmatica.* Finally, the latter species has a small but distinct tooth in the left valve, which could be an evolutionary innovation, as compared with the edentulous hinge in the Mississippian species of the genus.

Considering the fact that all known Mississippian species of *Cypricardella* are pre-Chester (*Cypricardella* sp. is recorded, but not illustrated by Easton, 1942, p. 85, from the Pitkin limestone of Arkansas), the appearance of *C.* (?) *enigmatica* in the Redoak Hollow is separated from them by a considerable stratigraphic interval, which could well account for the evolutionary changes in the shell, as just outlined. These differences perhaps are sufficient to institute on this form a new genus, but it seems prudent to postpone it until comparative study is made with the types of *Cypricardella,* instead of with its published insufficient descriptions and illustrations.

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PALEONTOLOGY OF NORTHWESTERN VERMONT. VI. THE EARLY MIDDLE CAMBRIAN FAUNA

ALAN B. SHAW
Shell Oil Company, Denver, Colorado

ABSTRACT—A new fauna of early Middle Cambrian age is provisionally correlated with the *Albertella* zone of western North America. The fauna consists of 1 sponge, 5 brachiopods, 1 (or 2) gastropods, 1 hyolithid, 1 cystid, and 10 trilobites. None is referred to a new genus, but the following new species are named: *Nisusia cloudi* and *N? howelli* (brachiopods), *Coreospira? raymondi* (gastropod), and *Chancia rasettii*, *Syspacephalus cadyi*, *Zacanthoides kelsayae*, and *Kootenia boucheri* (trilobites).

INTRODUCTION

THIS paper supplements the general summary of the Lower and lower Middle Cambrian faunas previously published (Shaw, 1954) and names some of the species previously referred to only by genus. The stratigraphic and geographic distribution of the collections mentioned herein has already been described (Shaw, 1954, p. 1042–1044) and will not be repeated here except for a brief listing.

Loc. SA-C-8. Lower Parker slate, about 580 feet above base.

Locs. SA-EC-3, SA-EC-2 and SA-EC-6. Upper Parker slate, about 50 feet above middle dolomite.

Loc. SA-EC-1. Upper Parker slate, about 190 feet above middle dolomite.

Loc. SA-NE-9. Limestone conglomerate in upper Parker slate. The stratigraphic level of the last locality is unknown, but probably is about the same as Loc. SA-EC-1. All specimens are from pebbles, but because of the similarity of pebbles and matrix it is impossible to distinguish them on fresh surfaces. Only one pebble was extracted in such a manner as make it certain that no matrix or other pebbles were included. This was called Pebble A. Its fauna is listed here to show those species that certainly occur together.

Syspacephalus cadyi (10 cranidia)
Mexicella stator (1 cranidium)
Zacanthoides kelsayae (2 cranidia; 1 pygidium)
Kootenia boucheri (2 cranidia; 2 pygidia)
Orriella sp. indet. (1 cranidium; 4 pygidia)
Orriella? sp. indet. (1 cranidium, listed in 1954 as *Corynexochides* sp. indet.)
Indeterminate cranidia (2).

Type and representative specimens have been deposited with the Museum of Comparative Zoology at Harvard College (MCZ) and the Department of Geology, University of Wyoming (UW). Other specimens have been retained in the personal collections of Franco Rasetti and the author.

ACKNOWLEDGMENTS

I am indebted to Dr. Franco Rasetti who accompanied me in the field in 1948 and assisted in collecting the fauna from Locality SA-NE-9. It was he who first pointed out its Middle Cambrian age to me. Mr. J. Maurice Boucher, on whose land this outcrop lies, generously assisted Dr. Rasetti and me in quarrying the fauna. Dr. H. B. Whittington photographed *Mexicella stator* for me. A grant-in-aid from the Graduate Research Council of the University of Wyoming greatly helped the remaining photography. The Shell Oil Company arranged for final typing of the manuscript, and the paper is published by permission of the Company.

SYSTEMATIC PALEONTOLOGY

Phylum PORIFERA

SPONGE SPICULES

Pl. 99, fig. 1

Sponge spicules SHAW, 1954, Geol. Soc. Amer. Bull., vol. 65, p. 1043.

Seven hexactine spicules were collected at Locality SA-EC-1, and the best preserved is figured. Since all specimens are external molds, the original shell matter cannot be determined.

Phylum BRACHIOPODA
Class ARTICULATA
Order ORTHIDA
Superfamily ORTHACEA Waagen, 1884
Family NISUSIIDAE Schuchert & Cooper, 1931
(=NISUSIINAE Walcott & Schuchert, 1908)
Genus NISUSIA Walcott, 1905
NISUSIA FESTINATA (Billings), 1861
Pl. 99, fig. 2–4,9(?)

Nisusia festinata SHAW, 1954, Geol. Soc. Amer. Bull., vol. 65, p. 1043; ——, 1955, Jour. Paleont., vol. 29, p. 789, pl. 76, fig. 3–6.

This is an uncommon species in the upper Parker slate, being replaced by *Nisusia cloudi*, but specimens are known from Locality SA-EC-1. Its distinctive features are the irregularity of its costae, its transverse shape, and its maximum width, which is at the hinge line.

Stratigraphic range.—Upper Dunham dolomite through Locality SA-EC-1, about 190 feet above the middle Parker dolomite. This is the most common *Nisusia* in the lower Parker slate.

NISUSIA CLOUDI Shaw, n. sp.
Pl. 99, fig. 5–8

Nisusia aff. *N. amii* SHAW, 1954, Geol. Soc. Amer. Bull., vol. 65, p. 1043; ——, 1955, Jour. Paleont., vol. 29, p. 789, pl. 76, fig. 7,8.

Most of the brachiopods collected from Locality SA-EC-1 belong to what appears to be a new species closely related to *Nisusia amii*. They differ from that species in having the rough irregular ribbing of *N. festinata* instead of the smooth fine ribbing of *N. amii*. It is possible that the Parker form is a transition from *N. festinata* to *N. amii*.

Undistorted shells are about 15 mm. wide. The ribs are irregular, thickening slightly around what seem to be spine bases. Ribs increase by both intercalation and bifurcation. The cardinal margin is straight and is uniformly narrower than the greatest width of the shell. This contrasts with *N. festinata* in which the hinge line is the widest point on the shell.

This species is named in honor of Dr. Preston E. Cloud, Jr.

Holotype.—UW IT-258n. Remaining specimens in UW IT-258 and IT-259 are paratypes. Plesiotype, MCZ 9355.

Occurrence.—Locality SA-EC-1.

NISUSIA? HOWELLI Shaw, n. sp.
Pl. 99, fig. 10

Nisusia, n. sp. SHAW, 1954, Geol. Soc. America Bull., vol. 65, p. 1043; ——, 1955, Jour. Paleont., vol. 29, p. 789.

A single ventral valve of what seems to be a new species of *Nisusia* has been found

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EXPLANATION OF PLATE 98

FIG. *1–9—Kootenia boucheri* Shaw, n. sp. *1*, Large flattened internal mold cranidium, ×2, MCZ 5007, Loc. SA-EC-1; *2*, nearly undistorted internal mold of cranidium, ×2, MCZ 5006, Loc. SA-EC-1; *3–5*, dorsal, lateral, and anterior views of holotype cranidium, ×1, MCZ 5014, Loc. SA-NE-9; *6*, internal mold of medium-sized pygidium, ×1½, MCZ 5002, Loc. SA-EC-1; *7*, large, smooth, gerontic pygidium, ×1, MCZ 5015, Loc. SA-NE-9; *8*, medium-sized pygidium and small cranidium, ×1, MCZ 5016, Loc. SA-NE-9; and *9*, Internal pygidial mold, ×2, MCZ 5000, Loc. SA-EC-1.

10—Hyolithes americanus Billings, 1871 (?). Flattened shell, typical of those present in upper Parker slate, ×2. UW A11186a. Loc. SA-EC-1.

11,12—Kochina sp. indet. Dorsal and anterior views of fragmentary cranidium, ×2. MCZ 5020. Loc. SA-NE-9.

13—Coreospira? raymondi Shaw, n. sp. Holotype conch, slightly crushed, ×6. MCZ 5006. Loc. SA-EC-1.

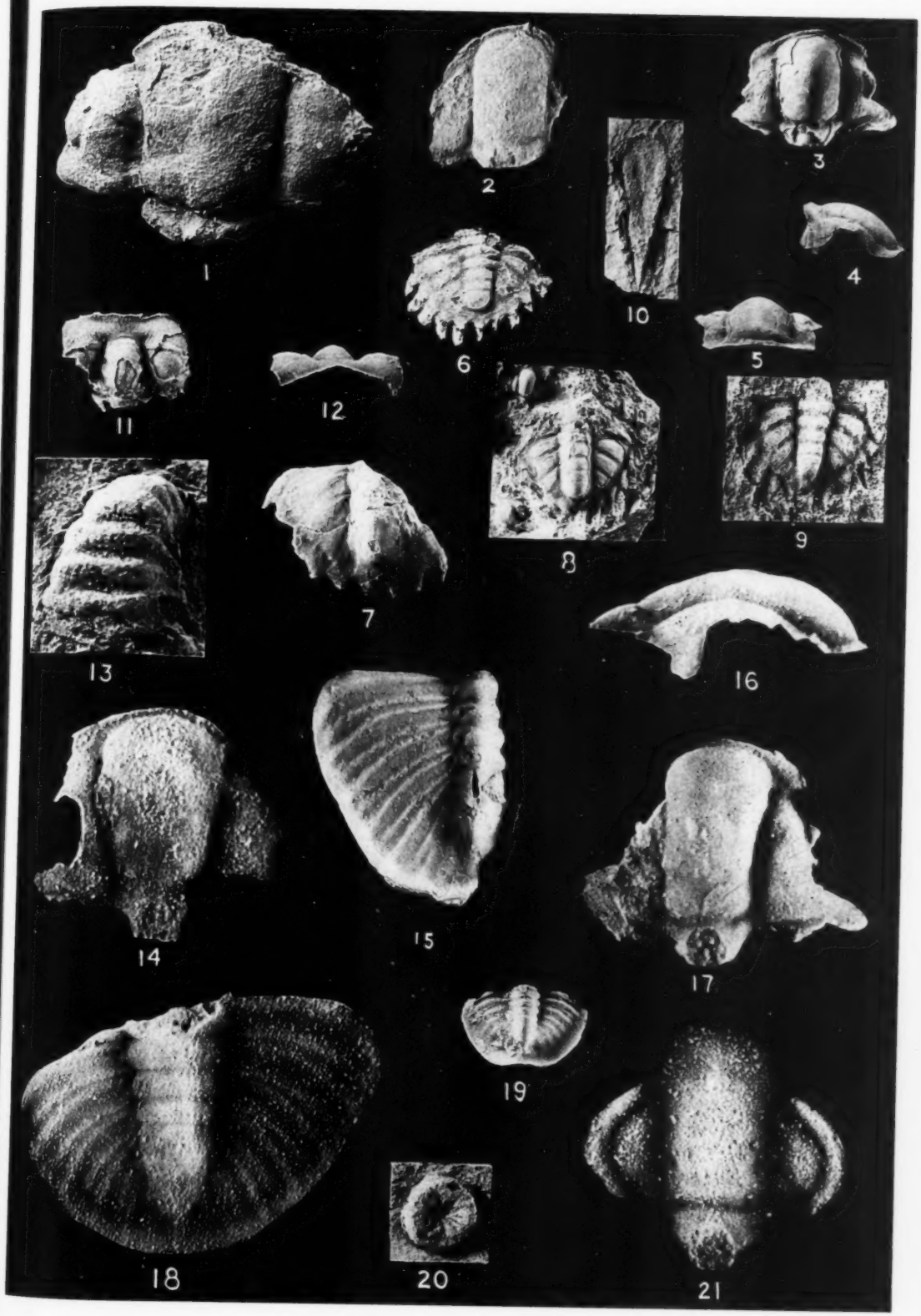
14—Orriella? sp. indet. Immature cranidium referred to *Corynexochides* in 1954, ×16. MCZ 5041. Loc. SA-NE-9 (Pebble A).

15–18—Orriella sp. indet. *15*, Rubber squeeze of largest external pygidial mold, ×2, MCZ 5010; *16,17*, best preserved cranidium, ×12½; and *18*, small pygidium, ×12, MCZ 5055. All from Loc. SA-NE-9; *16–18* from Pebble A.

19—Athabaskia sp. indet. Unique pygidium, ×2. MCZ 5013. Loc. SA-NE-9.

20—Cystid columnal. Rubber squeeze of unique external mold, ×2. UW IT-181. Loc. SA-EC-1.

21—Zacanthoides kelsayae Shaw, n. sp. Unique meraspid (?) cranidium, ×21. MCZ 5056. Loc. SA-NE-9 (Pebble A).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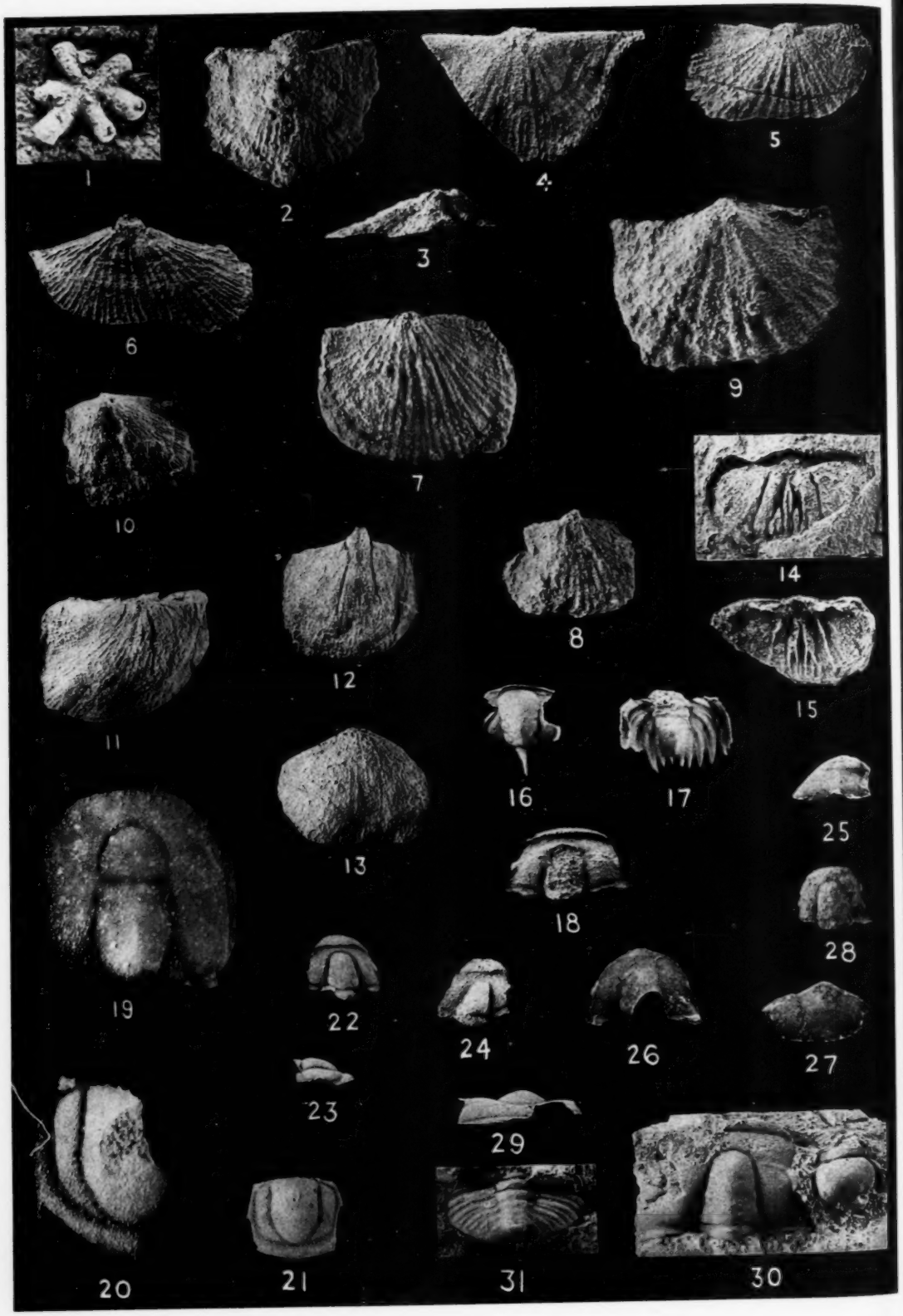
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in the lower Parker at Locality SA-C-8. The shell is transverse, faintly sulcate, with a well developed apsacline interarea. The xenidium is present as in all *Nisusiae*. The distinctive feature of the shell is its regular costellate ribbing, which is unlike the irregular, rough, coarser ribbing of the other species in the Parker.

This shell was at first tentatively identified as *Wimanella? orientalis* (Whitfield), 1884, because of the fineness of the ribbing, but when the holotype of the latter was studied it showed that the two are not related. The xenidium and transverse shape clearly differentiate *Nisusia howelli* from *W? orientalis*. The most nearly similar species appears to be *"Nisusia" oriens* Walcott, 1924, which Schuchert and Cooper (1932, p. 46) would remove from *Nisusia* to an unspecified genus.

Holotype.—MCZ 9353.

Family FINKELNBURGIIDAE Schuchert & Cooper, 1932

"FINKELNBURGIA" sp.

Pl. 99, fig. 13–15

"Finkelnburgia" sp. indet. SHAW, 1954, Geol. Soc. Amer. Bull., vol. 65, p. 1043.

A single ventral valve of an unidentified brachiopod was found at Locality SA-EC-3. It bears a pseudospondylium, moderately well-developed teeth, an open delthyrium and prominent, raised pallial trunks very similar in structure to those of *Finkelnburgia bellatula* (Ulrich and Cooper, 1938, pl. 25, fig. 28; Schuchert and Cooper, 1932, pl. 13, fig. 18) and *F. osceola* (Schuchert and Cooper, 1932, text-fig. 16c). Because of these similarities to *Finkelnburgia* this specimen is referred to the genus in order to point up the relationship, but there is no implication that it belongs to the genus in its strict sense.

EXPLANATION OF PLATE 99

FIG. *1*—Sponge spicule. Rubber squeeze from natural mold, ×5.5. UW A11187. Loc. SA-EC-1. From negative by Charles Pugh.

2–4—*Nisusia festinata* (Billings), 1861. *2,3*, Rubber squeeze from natural mold (now destroyed) of ventral valve, ventral and posterior views, ×2, Loc. SA-EC-3; and *4*, alate dorsal valve, ×2. MCZ 9357a. Loc. SA-C-8.

5–8—*Nisusia cloudi* Shaw, n. sp. *5,6*, Dorsal interior molds, ×2, paratypes, UW IT-259p and IT-258K; *7*, best preserved dorsal interior mold, ×2, holotype, UW IT-258n; and *8*, interior mold of small (dorsal?) valve, X2, MCZ 9355. All specimens from Loc. SA-EC-1.

9—*Nisusia festinata* (Billings), 1861 (?). Internal mold of small ventral valve, having unusually coarse, widely spaced ribs for the species, ×4½. MCZ 9356. Loc. SA-EC-1.

10—*Nisusia? howelli* Shaw, n. sp. Rubber squeeze (UW IT-182) from natural exterior mold of ventral valve, ×2. Holotype: MCZ 9353. Loc. SA-C-8.

11,12—Undetermined orthoid brachiopod. Internal molds of two dorsal valves of undetermined affinities, ×2. Brachiophore plates are more easily seen in Fig. 12. MCZ 9347b and 9347a. Loc. SA-EC-1.

13–15—*"Finkelnburgia"* sp. *13*, Unique dorsal internal mold, ×2, MCZ 9354, Loc. SA-EC-1; and *14,15*, natural internal mold of ventral valve and rubber squeeze, ×1. UW A11185. Loc. SA-EC-3.

16,17—*Zacanthoides kelsayae* Shaw, n. sp. *16*, Paratype cranidium, ×2, MCZ 5018; and *17*, holotype pygidium, ×2, MCZ 5019. Both from Loc. SA-NE-9.

18—*"Ptychoparella"* sp. indet. Internal cranidial mold, ×2. MCZ 5042. Loc. SA-C-8.

19–21—*Peronopsis* sp. indet. *19*, Cephalon, ×12½, MCZ 5056; *20*, fragment of pygidium retaining marginal spine, ×16, MCZ 5049; and *21*, best pygidium, lacking marginal spines, ×7, MCZ 5054.

22–24—*Syspacephalus cadyi* Shaw, n. sp. *22,23*, Dorsal and lateral view of holotype cranidium, ×2, MCZ 5017, Loc. SA-NE-9; and *24*, internal cranidial mold, ×2, MCZ 5005, Loc. SA-EC-1.

25–28—*Mexicella stator* (Walcott), 1916. *25–27*, Lateral, dorsal and anterior views of cranidium, ×3, MCZ 5023, Loc. SA-NE-9, From negative by Dr. H. B. Whittington; and *28*, internal cranidial mold, ×2, MCZ 5050a, Loc. SA-EC-1.

29–31—*Chancia rasettii* Shaw, n. sp. *29,30*, Dorsal and anterior views of holotype cranidium, ×2, MCZ 5021. Associated cranidium is small individual of *Kootenia boucheri;* and *31*, assigned paratype pygidium, ×2, MCZ 5022. All from Loc. SA-NE-9.

A unique, costellate, convex dorsal valve has been found at Locality SA-EC-1, and it may belong to this species. There are traces of short brachiophore plates, which seem to stand vertically (unlike the Finkelnburgiidae), the notothyrium is open, and there is no visible trace of a cardinal process, although the poor preservation of the specimen may account for its absence. This specimen resembles the two dorsal valves next to be described, but it lacks their strong brachiophore plates.

Plesiotypes.—MCZ 9354 (Loc. SA-EC-1) and UW A11185 (Loc. SA-EC-3).

Undetermined Orthoid Brachiopod
Pl. 99, fig. 11–12

Undetermined orthoid Shaw, 1954, Geol. Soc. Amer. Bull., vol. 65, p. 1043.

Two specimens of an orthoid dorsal valve have been found at Locality SA-EC-1. They are marked by brachiophore plates that seem to give rise to a pair of long septum-like ridges extending about 7/10 of the way to the anterior margin. These "septa" may be ridges bounding the muscle track.

The muscle field seems to have been better impressed on my specimens than in most Parker brachiopods. Because of distortion, it is impossible to distinguish true muscle marks from pressure-caused wrinkles in the shell.

Plesiotypes.—MCZ 9347a,b.

Phylum Mollusca
Class Gastropoda
Genus Coreospira Saito, 1936?
Coreospira? raymondi Shaw, n. sp.
Pl. 99, fig. 13

(?) *Stenotheca rugosa* Walcott, 1886, U. S. Geol. Survey, Bull. 30, p. 129.
Stenotheca rugosa Schuchert, 1937, Geol. Soc. Amer. Bull., vol. 48, p. 1034.
Helcionella aff. *H. paupera* Shaw, 1954, Geol. Soc. Amer. Bull., vol. 65, p. 1034.

Further study of the three specimens originally referred to *Helcionella* by Shaw has shown that they may be referable to *Coreospira* and that they are a new species. The shell curves through about 180°. The aperture apparently flared posteriorly but did not anteriorly. There are seven distinct transverse ribs and possibly a faint eighth rib (or more?) on the apical end. The maximum height normal to the plane of the aperture is 4 mm.

The species is named in honor of the late P. E. Raymond, who collected the holotype.

Holotype.—MCZ 5006.

Occurrence.—Locality SA-EC-1.

Gastropod indet.

Scenella sp. Schuchert, 1937, Geol. Soc. Amer. Bull., vol. 48, p. 1034.

Schuchert reported a *Scenella* from his Loc. XVIII (=Locality SA-EC-1 of this paper). Collections made there during this study have not confirmed its presence.

Mollusca (?) incertae sedis
Hyolithes americanus Billings, 1871 (?)
Pl. 98, fig. 10

Hyolithes americanus Schuchert, 1937, Geol. Soc. Amer. Bull., vol. 48, p. 1034; ——, 1954, Geol. Soc. Amer. Bull., vol. 65, p. 1042, p. 1043; ——, 1955, Jour. Paleont., vol. 29, p. 786.

A flattened hyolithid tentatively identified with *Hyolithes americanus* is abundant in the Parker slate, but preservation makes positive identification impossible. A typical specimen is figured.

Occurrence.—At Localities SA-C-8 and SA-EC-1. Also present through the Lower Cambrian beds of the Parker slate and at the top of the Dunham dolomite (details in Shaw, 1954; 1955).

Phylum Echinodermata
Subphylum Pelmatozoa
Class Cystoidea
"Eocystites" sp. indet.
Pl. 98, fig. 20

Eocystites? sp.? Walcott, 1886, U. S. Geol. Survey Bull., 30, p. 46.
Eocystites Walcott, 1891, U. S. Geol. Survey 10th Ann. Rept., pt. 1. p. 607.
Cystid plates Shaw, 1954, Geol. Soc. Amer. Bull., vol. 65, p. 1043.
Eocystites sp. indet. Shaw, 1955, Jour. Paleontology, vol. 29, p. 785.

One characteristic columnal is figured. No specimens are truly identifiable, and the reference to "*Eocystites*" merely follows Walcott's precedent.

Stratigraphic range.—From 140 feet above the base of the Parker slate to Locality SA-EC-1.

Phylum ARTHROPODA
Class TRILOBITA
Order AGNOSTIDA
Family PERONOPSIDAE Westergård, 1936
Genus PERONOPSIS Hawle & Corda, 1847
PERONOPSIS sp. indet.
Pl. 99, fig. 19–21

(?) *Peronopsis* sp. indet. no. 1 RASETTI, 1948, Jour. Paleont., vol. 22, p. 320, pl. 45, fig. 8–11.
Kormagnostus sp. indet. SHAW, 1954, Geol. Soc. Bull., vol. 65, p. 1044.
Peronopsis sp. indet. SHAW, 1954, *loc. cit.*

Cephalon typical of the genus with smooth surface. Glabella composed of two lobes; the posterior lobe has an obscure node. The anterior lobe is slightly pointed in front. Cheeks broadly confluent in front without furrows. Rim narrow, of even width. Marginal furrow not well impressed; rim set off by sharp break in slope of test. The slightly pointed anterior glabellar lobe and the less distinct marginal furrow are different from the *Peronopsis* figured by Rasetti.

The pygidium shows no apparent differences from that figured by Rasetti. The axial lobe is virtually smooth, except for an elongate median node. There is an inbend of the dorsal furrows anteriorly, opposite what would be the second lobe. Behind the axial lobe the dorsal furrows join the marginal furrows. Pleural lobes are smooth and average about half as wide as the axial lobe. The rim of the pygidium is flat-topped and set off by a shallow marginal furrow posteriorly. Laterally, the marginal furrow becomes shallower, until at the middle of each side of the furrow is gone, and there is only a sharp change in the slope of the test. Small spines are present on the rim.

Remarks.—This species is separated from Rasetti's *Peronopsis* No. 1 only by slight differences, which, it appears, are not of specific value. However, there are not enough specimens now at hand to be sure of the identity of the two forms.

By error, a preliminary identification of two pygidia of this species as *Kormagnostus* was not eliminated from the faunal list published in 1954. The total number of specimens of *Peronopsis* sp. includes 3 cephala and 2 pygidia.

Plesiotypes.—MCZ 5049, 5054, 5056.

Occurrence.—Locality SA-NE-9.

Superfamily PTYCHOPARIIDEA Richter, 1932
Family ALOKISTOCARIDAE Resser, 1939
Genus CHANCIA Walcott, 1924
CHANCIA RASETTII Shaw, n. sp.
Pl. 99, fig. 29–31

Chancia sp. SHAW, 1954, Geol. Soc. Amer. Bull., vol. 65, p. 1043.

The cranidium is subquadrate with wide posterior limbs. The glabella is narrow, elongate, and gently rounded in front. The glabellar furrows are so faint that it is difficult to decide certainly on the number of pairs present, but there seem to be three. The occipital furrow is narrow and straight; the occipital ring is marked by a small node, which is very obscure on some individuals. The facial sutures diverge slightly before the eyes, forming a wide frontal limb; they diverge abruptly behind the eyes, forming wide strap-like posterior limbs. The posterior limb is about twice as wide as the occipital ring and the fixed cheeks are only slightly less wide than the glabella. The palpebral lobes are short, and they lie at the mid-length of the cranidium and are equipped with low ocular ridges. The frontal limb is long, comprising a narrow border and a wide brim. The surface of the test is smooth.

The assigned pygidium is transverse. The axial lobe consists of five or six segments plus the articulating half-ring and the terminal segment; it is narrow and does not extend quite to the rear margin. The pleural lobes show both pleural grooves and interpleural furrows, and both run to the margin of the pygidium so that there is no border.

Remarks.—This species has a much narrower cranidial border than the genotype of *Chancia*, but Rasetti (1951, p. 212ff) has placed such species in the genus. It is similar to *C. bigranulosa* Rasetti, 1951, except that its surface is smooth; no pygidium was assigned to *C. bigranulosa*.

It is a pleasure to name this new species for Dr. Franco Rasetti, who aided in the discovery and collection of the type specimens.

Holotype.—MCZ 5021 (cranidium).

Paratypes.—MCZ 5022 (pygidium); UW-IT-259; Rasetti collection; the author's collection.

Occurrence.—Locality SA-NE-9.

Genus KOCHINA Resser, 1935
KOCHINA sp. indet.
Pl. 99, fig. 11,12

Kochina sp. indet. SHAW, 1954, Geol. Soc. Amer. Bull., vol. 65, p. 1044.

Four poorly preserved cranidia of what appears to be a species of *Kochina* have been found at Locality SA-NE-9. The most nearly complete is figured. The glabella is short, moderately truncated, and marked by three pairs of short glabellar furrows and a well impressed occipital furrow. The occipital ring is not preserved on any of the specimens. The dorsal furrow is deep at the sides of the glabella but shallow in front of it. The fixed cheeks are elevated but flat-topped and are marked by prominent ocular ridges. The fixed cheeks and posterior limbs seem to be slightly wider than the glabella, but preservation is poor. The eyes are short and lie about opposite the midlength of the glabella. The brim is concave in the middle but convex at the sides. Over the entire surface of the brim there is a network of faint radiating nervures. A marginal furrow is present and is moderately deep. The border has not been preserved. The facial sutures hardly flare at all in front of the eyes and but slightly so behind so that a nearly quadrate cranidium is formed.

Plesiotype.—MCZ 5020. Additional specimens in Rasetti collection.

Occurrence.—Locality SA-NE-9.

Family PTYCHOPARIIDAE Mathew, 1888
Subfamily PTYCHOPARIINAE Matthew, 1888
Genus PTYCHOPARELLA Poulsen, 1927
"PTYCHOPARELLA" sp. indet
Pl. 99, fig. 18

Ptychoparella sp. indet. SHAW, 1954, Geol. Soc. Amer. Bull., vol. 65, p. 1043.

The general shape of the cranidium is transverse. The glabella is damaged, but it is truncato-conical in outline. Sharp ocular ridges curve back to small palpebral lobes that lie almost at the mid-length of the cranidium. The posterior limbs are slightly wider than the glabella and bear a well-impressed marginal furrow. The rim is narrow and sharp, but the figured specimen is an internal mold, and the interior impression of the border is commonly thinner than is the exterior.

Remarks.—This cranidium is not well enough preserved to allow certain identification. It is almost certainly not a true *Ptychoparella*. It appears to be close to "*P.*" *kindlei* Resser, 1937.

Plesiotype.—MCZ 5042.

Occurrence.—Locality SA-C-8.

Subfamily ANTAGMINAE Hupé, 1953
Genus SYSPACEPHALUS Resser, 1936
SYSPACEPHALUS CADYI Shaw, n. sp.
Pl. 99, fig. 22–24

Syspacephalus sp. A SHAW, 1954, Geol. Soc. Amer. Bull., vol. 65, p. 1043, 1044.

The species is known only from the cranidium, which averages about 5 millimeters long. The glabella is practically smooth, but shows traces of two pairs of poorly impressed glabellar furrows; the occipital furrow is well developed and separates an occipital ring marked by a prominent node. The dorsal furrows are well impressed and delimit the slightly truncated glabella all around. The small eyes lie opposite the anterior glabellar furrow and nearly at the cranidial midlength. The fixed cheeks are about two-thirds as wide as the glabella opposite the eyes. The posterior limbs, which are slightly wider than the occipital ring, are marked by a deep marginal furrow. Anteriorly, there is a moderately wide brim set off from the border by a marginal furrow. The facial sutures taper inward from the rear of the head toward the front in an almost undeflected line.

Remarks.—The cranidia found at Locality SA-EC-1 are internal molds in slate, and differ from limestone preservations in the much shallower dorsal furrows and narrower and more abruptly truncate glabella. Other features are essentially alike in both types of preservation.

Holotype.—MCZ 5017.

Paratypes.—MCZ 5005, 5006; UW IT-261, IT-267; Rasetti collection; the author's collection.

Occurrence.—The most abundant form at Locality SA-NE-9; uncommon at Locality SA-EC-1.

Superfamily AGRAULIDEA Hupé, 1953
Family AGRAULIDAE Raymond, 1913
Genus MEXICELLA Lochman, 1948
MEXICELLA STATOR (Walcott), 1916
Pl. 99, fig. 25–28

Agraulos stator WALCOTT, 1916, Smithsonian Misc. Coll., vol. 64, no. 3, p. 173–174, pl. 36,

fig. 6; ——, 1917, Smithsonian Misc. Coll., vol. 67, no. 2, p. 28, pl. 6, fig. 6.
Alokistocare stator Resser, 1935, Smithsonian Misc. Coll., vol. 93, no. 5, p. 9.
Mexicella stator LOCHMAN, 1948, Jour. Paleont. vol. 22, p. 453,457; ——, RASETTI, 1951, Smithsonian Misc. Coll., vol. 116, no. 5, p. 231–232, pl. 20, fig. 14–19; —— SHAW, 1954, Geol. Soc. Amer. Bull. vol. 65, p. 1043,1044.

It is surprising to find a species from British Columbia in northwestern Vermont, but I can distinguish no important differences between the upper Parker form and the specimens illustrated by Rasetti.

Plesiotypes.—MCZ 5023; Rasetti collection; University of Wyoming; the author's collection.

Type locality.—USNM Loc. 35c, Ross Lake shale member of Cathedral formation (Rasetti, 1951, p. 232).

Occurrence in Vermont.—Localities SA-NE-9 and SA-EC-1.

Superfamily CORYNEXOCHIDEA Kobayashi, 1936
Family ZACANTHOIDIDAE Swinnerton, 1915
Genus ZACANTHOIDES Walcott, 1888
ZACANTHOIDES KELSAYAE Shaw, n. sp.
Pl. 99, fig. 16,17
Pl. 98, fig. 21

Zacanthoides sp. SHAW, 1954, Geol. Soc. Amer. Bull., vol. 65, p. 1044.

Known from isolated cranidia and pygidia. Cranidium typical of the genus with few distinguishing characteristics. Glabella occupies most of the cranidium, expanded anteriorly. Four pairs of short glabellar furfows and a well impressed occipital furrow mark the glabella. The occipital ring is small and produced into a long narrow spine. The dorsal furrow is shallow but present all around. Fixed cheeks and posterior limbs are narrow, the former essentially comprising the palpebral lobes. A well impressed palpebral furrow runs from the marginal furrow, in the rear, forward to a point opposite the second glabellar furrow. The frontal limb is short, consisting of an abruptly upturned border separated from the glabella by the dorsal furrow. The facial sutures flare before the eyes.

The pygidium is the more distinctive of the two shields. The axial lobe shows three segments plus the articulating half-ring and a large terminal segment. Pleural furrows and interpleural grooves extend to the margin of the shield, which has no defined border. There are five marginal spines on each side. The distinctive feature of the pygidium is its transverse shape combined with rather long spines. Other species of *Zacanthoides* with a transverse tail have small pygidial spines, while those species with long spines have more elongate shape than does *Z. kelsayae.*

This species is named for Miss Ann Kelsay, who assisted me in the preparation of this and other manuscripts.

Holotype.—MCZ 5019 (pygidium).

Paratypes.—MCZ 5018 (cranidium); UW IT-144, IT-265; Rasetti collection; the author's collection.

Occurrence.—Locality SA-NE-9.

Family DORYPYGIDAE Kobayashi, 1935
Subfamily DORYPYGINAE Kobayashi, 1935

Genus KOOTENIA Walcott, 1889
KOOTENIA BOUCHERI Shaw, n. sp.
Pl. 99, fig. 30
Pl. 98, fig. 1–9

Kootenia sp. A SHAW, 1954, Geol. Soc. Amer. Bull., vol. 65, p. 1043,1044.
Kootenia boucheri SHAW (*nomen nudum*), 1955, Jour. Paleont. vol. 29, p. 787.

The glabella is almost parallel-sided, expanding very slightly forward. Faint traces of the distal ends of two pairs of glabella furrows are visible on exfoliated specimens. The occipital furrow is completely impressed but is shallower mesially than distally. Dorsal furrows are not deep but are everywhere present. Two anterior pits lie in the furrows near the front end of the glabella. The fixed cheeks are gently arched, but their position is essentially horizontal. Eye-lines are lacking, but shallow palpebral furrows are present. The palpebral lobes are moderately long but are shorter than in the older species *K. marcoui;* they lie about opposite the midpoint of the glabella (including the occipital ring). The posterior limb is about equal in width to the occipital ring. The frontal limb is small, comprising mainly the flat border, the characteristic of the species. The test is thin and appears to bear microscopic granules, although it looks smooth to the naked eye.

The pygidium bears the 12 marginal spines typical of many Middle Cambrian *Kootenia.* In small and medium-sized specimens the furrows on both axial and pleural

lobes are normally impressed but several large pygidia over an inch wide show an effacement of all or nearly all furrows (Pl. aa, fig. 7) attributed to old age.

I am pleased to name this species *Kootenia boucheri* after Mr. J. Maurice Boucher, on whose land the holotype and most of the paratypes were found.

Remarks.—The species is distinguished from *K. marcoui* and from all species described by Rasetti from the Middle Cambrian of Quebec in lacking a rounded border on the front of the cranidium.

Holotype.—MCZ 5014 (cranidium from Locality SA-NE-9).

Paratypes.—From Locality SA-NE-9: MCZ 5015 (gerontic pygidium), MCZ 5016 (normal pygidium); UW IT-265, IT-268; Rasetti collection; the author's collection. From Locality SA-EC-1: MCZ 5000, 5002, 5006, 5008; the author's collection.

Occurrence.—Localities SA-EC-1, SA-EC-2, and SA-NE-9.

Family Dolichometopidae (Rasetti ?, 1951)
Subfamily Orriinae Hupé, 1953
Genus Orriella Rasetti, 1948
Orriella sp. indet.
Pl. 98, fig. 14–18

Orriella sp. indet. Shaw, 1954, Geol. Soc. Amer. Bull., vol. 65, p. 1044.
Corynexochides sp. indet. Shaw, *op. cit.*, p. 1043.

An apparently new species of *Orriella* is a rare member of the upper Parker fauna. The pleural furrows and interpleural grooves show at their distal ends the distinct pattern of *Orriella* rather than the merging pattern of *Orria*.

Five cranidia of the species have been found, but four are obviously immature, and the fifth is badly damaged. Therefore, the cranidium cannot be fully described, but it appears to resemble that of *O. gaspensis* closely in its long anteriorly-expanded glabella, wide posterior limbs, and narrow fixed cheeks. The length of the palpebral lobes also seems to be the same, but poor preservation makes the point uncertain. The immature heads show only faint traces of the glabellar furrows so deeply impressed in *O. gaspensis*.

Remarks.—The fragmentary cranidium (MCZ 5041) referred to *Corynexochides* in 1954 (Pl. 2, fig. 14) has been re-studied, and it is here referred to *Oriella?*.

Plesiotype.—MCZ 5010; cast of same, UW IT-260. Additional specimens: UW IT-261, IT-262, IT-263; Rasetti collection.

Occurrence.—Locality SA-NE-9.

Subfamily Dolichometopinae Walcott, 1916
Genus Athabaskia Raymond, 1928
Athabaskia sp. indet.
Pl. 98, fig. 19

Athabaskia sp. indet. Shaw, 1954, Geol. Soc. Amer. Bull., vol. 65, p. 1043.

A single pygidium of what seems to be an *Athabaskia* has been found at Locality SA-NE-9. It is transverse, with a squared posterior outline. The axial lobe falls short of the rear edge of the pygidium but is prolonged into a ridge that runs to the posterior margin. The rim is broad and concave. The pleural furrows and interpleural grooves extend a short distance onto the rim and disappear.

Measurements in millimeters are: maximum width, 11.0; anterior width at inner edge of rim, 8.9; anterior width of axial lobe, 2.3; approximate length of axial lobe including articulating half-ring, 5.3; sagittal length of pygidium, including half-ring, 7.3; sagittal length of half-ring, approximately 0.4.

Remarks.—This specimen is close to that of *Athabaskia* sp. indet. figured by Rasetti (1951, pl. 22, fig. 12) but is distinguishable by its shorter axial lobe.

Plesiotype.—MCZ 5024.

Occurrence.—Locality SA-NE-9.

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JOURNAL OF PALEONTOLOGY, VOL. 31, NO. 4, P. 793–795, PL. 100, JULY 1957

FLUORIDIZATION OF MICROFOSSILS

CHARLES F. UPSHAW, ROBERT G. TODD, AND BILLY D. ALLEN
University of Missouri, Columbia

ABSTRACT—Calcium carbonate microfossils treated with hydrofluoric acid are converted to calcium fluoride, which is translucent when wet. This process, termed fluoridization by the writers, provides a means for investigation of internal structures which is rapid and relatively simple. Procedures are described and applications of the process are discussed.

INTRODUCTION

WHILE macerating a calcareous shale sample with hydrofluoric acid for spore and pollen analysis, the writers noticed that a white precipitate was formed. It was noted that if hydrochloric acid was added to the sample before treatment with the hydrofluoric this precipitate was not obtained.

Foraminiferal tests were subjected to this treatment in order to observe its effect on calcareous objects of known size and structure. It was expected that the calcareous tests would be destroyed by the acid. Instead, the tests remained intact, and when immersed in water were translucent to transparent. In many specimens the internal features were clearly visible.

A search of the literature revealed that this process had been described by Cookson and Singleton (1954). They had obtained similar results while conducting pollen research. In their article and in a later one by Grayson (1956), fluorite, as determined by X-ray analysis, was reported to be the end-product. Grayson suggested applications of this technique but failed to include those which we consider to be most significant. Sohn (1956) described this method, placing particular emphasis on its value in ostracode studies. We believe this process, here termed fluoridization, to be worthy of rediscussion; we hope that a wider acquaintance with, and a consequent application of, this technique will be of benefit.

PROCEDURE

Calcareous microfossils are placed in a polyethylene container and covered with hydrofluoric acid. Concentrated acid may be used on the smallest forms, but the concentration should be decreased with an increase in specimen size. This is necessary since violent evolution of carbon dioxide may destroy larger specimens. After the sample has been in the acid for several minutes (until all reaction has ceased), it is decanted into a polyethylene funnel lined with filter paper. Water is added during the filtering process until all acid has been washed from the sample. The filter paper is placed under the microscope and the wet specimens are transferred to a slide. The specimens are then covered with a mounting medium and a cover slip is applied.

Various mounting media may be used. Pure glycerine is suitable for temporary mounts and provides the advantage of allowing manipulation of the specimens. A good semipermanent mount may be made in glycerine jelly to which various biological stains may be added for background contrast. Commercial diaphane provides a more permanent mount, at the same time affording sufficient contrast for photomicrography; this eliminates the necessity of staining.

If the specimens are allowed to dry they again become opaque, and air accumulates within the chambers. The air must be displaced before immersion in the mounting medium; otherwise air bubbles will be trapped within the chambers, obscuring the internal features. The use of glycerine jelly requires care, for the chambers must remain filled with water until covered by the mounting medium. Since water is immiscible in diaphane, it was found that drying the specimens and immersing them in alcohol preparatory to mounting displaces the air.

Observation by transmitted light at magnification of 100 diameters gives exceptionally clear views of internal features. Variations in focus reveal details of wall structure, pores, spines, and other elements.

APPLICATIONS

Taxonomy.—Advantages of fluoridization in taxonomic studies are readily apparent. For example, it can be of great assistance in classification, distinction of microspheric and megalospheric forms, and the study of the origin and evolution of various groups of the foraminifers. This technique may be highly useful in the distinction between members of the *Robulus-Marginulina-Dentalina-Nodosaria* series. Another example is that agglutinated forms which contain a preponderance of calcium carbonate cement are similarly converted to translucency. This makes it possible to readily distinguish between such similar forms as *Textularia* and *Spiroplectammina.*

Illustration.—Photomicrographs of translucent specimens are easily made and are a valuable supplement to conventional illustration. The accompanying plate shows photomicrographs of specimens chosen to illustrate a variety of features. The exposures were taken with a Bausch and Lomb Model H camera with a shutter speed of 1/50 of a second. Illumination was provided by an AO Universal microscope lamp. The camera was mounted over an AO Model 66 monocular microscope with an ocular of 10× and a 16 mm. objective with a numerical aperture of 0.25.

Accurate diagrammatic drawings may be easily made with a camera lucida or with a microprojector. Satisfactory microprojection may be obtained by placing a simple prism on the microscope eyepiece and substantially increasing light intensity.

Teaching Aid.—Transparent mounts should be of great aid in teaching micropaleontology. The student can more readily appreciate growth patterns, dimorphic forms, and structure of the test by observa tion o

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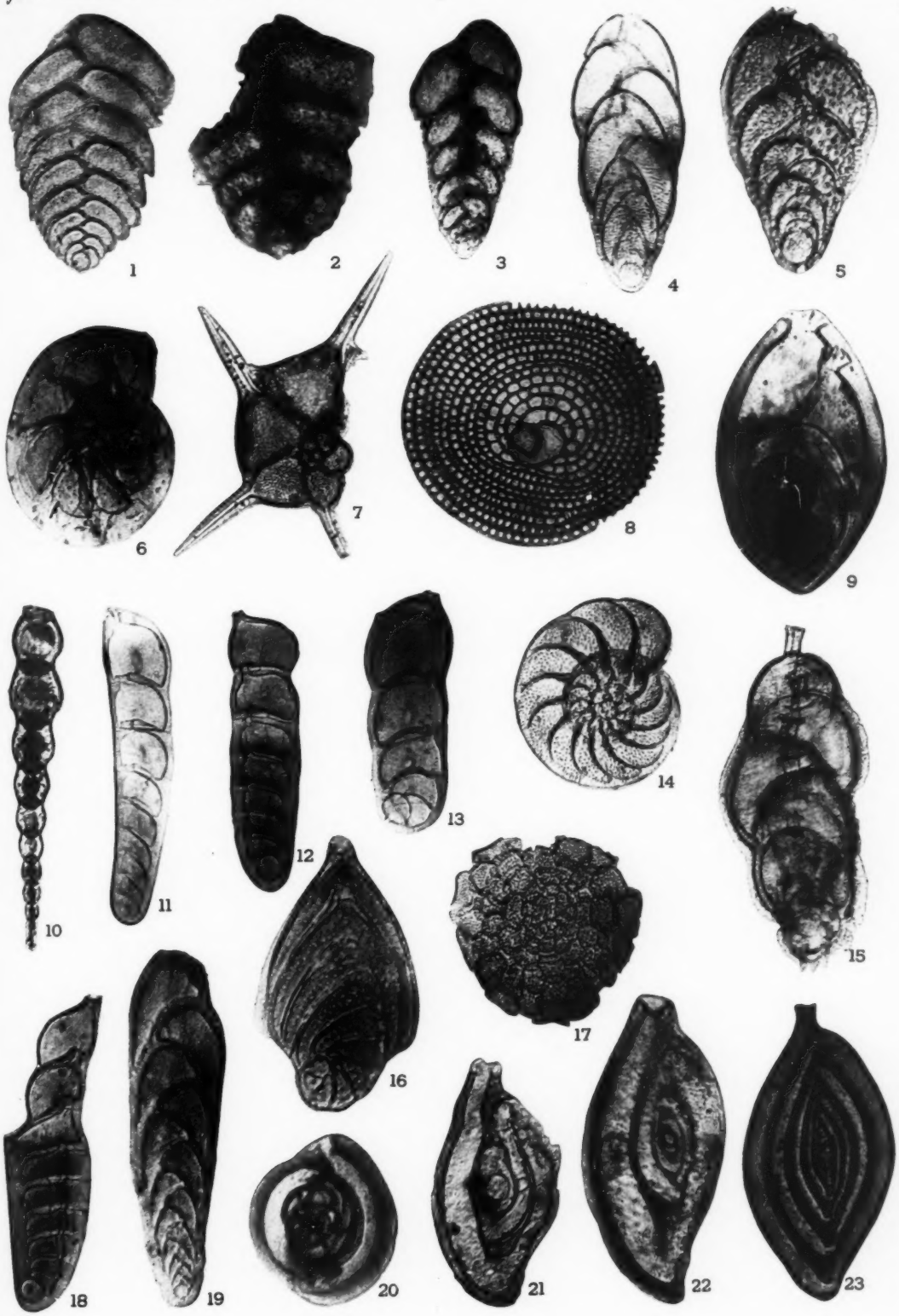
Explanation of Plate 100

All specimens are in diaphane mount except figures *5*, *15,16*, and *21* which are in glycerine jelly with stain.

Fig. *1*—*Textularia ripleyensis* W. Berry, ×67. U. Cret., Prairie Bluff fm., Oktibbeha Co., Miss.
2—*Spiroplectammina mississippiensis* (Cushman), ×200. Eocene, Yazoo clay, Clarke Co., Miss.
3—*Gaudryina rudita* Sandidge, ×50. U. Cret., Prairie Bluff fm., Oktibbhea Co., Miss.
4—*Bulimina prolixa* Cushman and Parker, ×98. U. Cret., Prairie Bluff fm., Oktibbeha Co., Miss.
5—*Bolivina mornhinvegi* Cushman, ×140. Oligocene, Chickasawahay ls., Wayne Co., Miss.
6—*Robulus limbosus* (Reuss) var. *hockleyensis* (Cushman and Applin), ×55. Eocene, Yazoo clay, Clarke Co., Miss.
7—*Hantkenina alabamensis* Cushman, ×110. View showing hollow nature of spines. Eocene, Yazoo clay, Clarke Co., Miss.
8—*Sorites* (?) sp. (?), ×37. Note multiple foramina. Miocene, Chipola fm., Calhoun Co., Fla.
9—*Guttulina problema* d'Orbigny, ×98. Showing structure of radiate aperture. Air bubble trapped in chamber. Oligocene, Chickasawhay ls., Wayne Co., Miss.
10—*Ellipsonodosaria paleocenica* Cushman and Todd, ×57. Paleocene, Clayton fm., Clay Co., Miss.
11—*Dentalina basiplanata* Cushman, ×48. U. Cret., Prairie Bluff fm., Oktibbeha Co., Miss.
12,13,18—*Marginulina texasensis* Cushman. *12*, ×45. *13*, ×51. *18*, ×44, an abnormal specimen showing evidence of injury during development. U. Cret., Prairiee Bluff fm., Oktibbeha Co., Miss.
14—*Anomalina* sp., ×70. U. Cret., Prairie Bluff fm., Oktibbeha Co., Miss.
15—*Uvigerina jacksonensis* Cushman, ×184. Eocene, Yazoo clay, Clarke Co., Miss.
16—*Palmula rugosa* (d'Orbigny) Cushman, ×68. U. Cret., Prairie Bluff fm., Oktibbeha Co., Miss.
17—*Planorbulinella larvata* (Parker and Jones), ×27. Oligocene, Chickasawhay ls., Wayne Co., Miss.
19—*Loxostomum* sp., ×75. U. Cret., Prairie Bluff fm., Oktibbeha Co., Miss.
20—*Pyrgo subsphaerica* (d'Orbigny), ×89. Miocene, Chipola fm., Calhoun Co., Fla.
21—*Spiroloculina* sp., ×90. Specimen showing a complete reversal in growth direction. Oligocene, Chickasawhay ls., Wayne Co., Miss.
22—*Spiroloculina spissa* Cushman and Todd, ×93. Oligocene, Chickasawahay ls., Wayne Co., Miss.
23—*Massilina decorata* Cushman, ×76. Eocene, Yazoo clay, Clarke Co., Miss.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this type of material. A microprojector may be used by the lecturer as an excellent teaching aid, or lantern slides may be made for use with a slide projector.

Conodonts.—It has been noted that conodonts are affected in much the same manner as calcium carbonate forms. The calcium phosphate is apparently altered to calcium fluoride. This may yield important results in the study of the phylogenetic relationships of this group. Particularly important is the distinction between the suborders Conodontiformes and Neurodontiformes and the study of the structure of simple cones.

The writers have not attempted to go beyond this initial stage in application of fluoridization to the conodonts. Further investigation of the problem is left to more competent students of the conodonts.

Other Forms.—Whorl cross-section, apical angle, nature of the columella, and characteristics of the protoconch of microgastropods can be observed in specimens treated by this process. Owing to the relatively greater thickness of the shell wall and the non-porous nature of the material, these forms become correspondingly more fragile during fluoridization. Applications of this process to the study of ostracodes, brachiopods, pelecypods, echinoids, and bryozoa have been described in the aforementioned articles.

SUMMARY

The treatment of calcareous microfossils with hydrofluoric acid is believed to be a valuable technique in micropaleontology. Although fluoridization may be less useful in the study of highly complex groups, the simplicity of the process in comparison with thin-section preparations and its varied applications suggest its usefulness to micropaleontologists.

The writers gratefully acknowledge the assistance of Dr. R. E. Peck, Dr. A. G. Unklesbay, and Mr. Jack Bobbitt who read the manuscript and offered valuable suggestions and criticisms.

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PALEONTOLOGICAL NOTE

HILGARDELLA, NEW NAME FOR THE CRETACEOUS BIVALVE HILGARDIA, PREOCCUPIED

LLOYD WILLIAM STEPHENSON
U. S. Geological Survey, retired

The new genus and species *Hilgardia compressa* Stephenson was described in vol. 30, no. 3, p. 752–753, 1956, of the Journal of Paleontology. I am indebted to Madame S. Freneix of the Laboratoire de Paleontologie, Muséum National D'Histoire Naturelle, Paris, France, for calling my attention to an earlier use of *Hilgardia* as a subgenus of *Nuculana* Link, by Harris & Palmer, in vol. 30, no. 117, p. 59, 1946, of the Bulletin of American Paleontology. In view of the preoccupied status of *Hilgardia* Stephenson I propose as a substitute the name *Hilgardella* Stephenson. The type species, now *Hilgardella compressa* (Stephenson), remains the same.

JOURNAL OF PALEONTOLOGY, VOL. 31, NO. 4, P. 796–808, PL. 101–102, 4 TEXT-FIG., JULY 1957

AN EDENTATE FROM THE PLEISTOCENE OF TEXAS

GIDEON T. JAMES
University of Houston, Houston

ABSTRACT—*Chlamytherium septentrionale* (Leidy), 1889, a fossil edentate recovered from the Pleistocene in Houston, Texas is described. It is the most nearly complete remains of the species known today and reveals many features that were previously unknown. The find represents the eighth locality for this species in Texas. This skeleton is specifically identical with the remains on which the genus *Holmesina* Simpson was founded. There are insufficient differences between this and the type species of the genus *Chlamytherium*, *C. humboldtii* Lund, 1838, to warrant two separate genera. Hence, *Holmesina* Simpson is considered a junior synonym of *Chlamytherium* Lund.

Several features resemble those in the Dasypodidae and Glyptodontidae and suggest for *Chlamytherium* an intermediate position between the two families, as previously proposed by Ameghino and Castellanos. It is also evident that the family Chlamytheridae (=Chlamydotheridae Ameghino, 1894) may be well founded.

INTRODUCTION

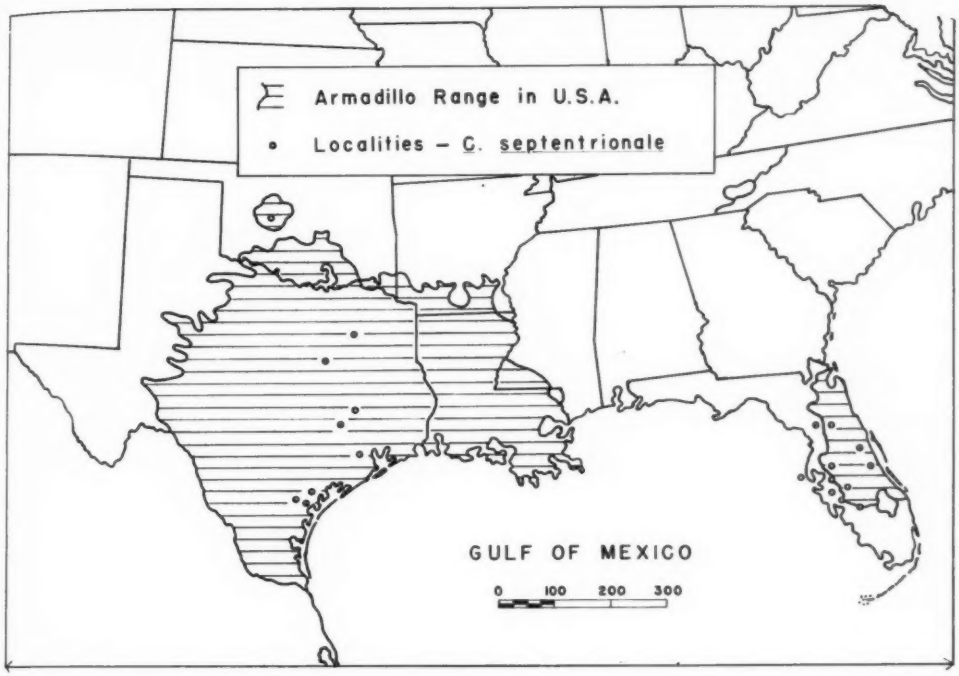
IT IS known that many animals migrated freely between the North and South American continents during the Pleistocene. Most of the migratory groups are well represented with fossils in both continents, but in the case of the Chlamytheres only one species, *Chlamytherium septentrionale*, is known to have existed in North America. There are twenty known localities for the species (Text-fig. 1); all are in North America, and all apparently are of late Pleistocene age.

Prior recoveries have resulted in such fragmentary remains that until now an adequate morphological description of the species has been lacking. It is the purpose of this paper to present a satisfactory description of the species. This has been made possible by the recovery of a specimen more nearly complete than any previously described.

The genus *Chlamytherium* Lund, 1838 (= *Chlamydotherium* Lund, 1839), for which *C. humboldtii* is the type species, was established by Lund on a left lower jaw with teeth and several dermal scutes collected from cave deposits in Minas Garaes, Brazil. The genus was first noted in North America when Leidy (1889A) described several dermal scutes collected from Peace Creek, Florida, and established the species *Glyptodon septentrionalis*. Leidy (1889B) soon recognized the close resemblance between these scutes and those figured by Lund for *C. humboldtii*. Subsequent finds of similar material in North America were referred by various authors to *C. humboldtii*. From remains collected at Vero Beach, Florida, a right lower jaw and several dermal scutes, Sellards (1915) reported that there are sufficient differences between the North American form and Lund's type to warrant two species. He revived Leidy's specific name, *septentrionalis*, but referred it to the genus *Chlamytherium*.

Simpson (1930) received additional Chlamythere remains, consisting of dermal scutes and a lower jaw collected at Bradenton Field, Florida, which he also regarded as distinct from *Chlamytherium humboldtii*. He assigned the name *Holmesina septentrionalis* to the material, basing his new genus on supposed differences between specimens from North America and from South America.

An examination of our specimen, which includes scute and jaw material identical to that described individually by Leidy, Sellards, and Simpson, shows that there are insufficient differences between *Holmesina septentrionalis* Simpson and *C. humboldtii* Lund to warrant generic separation. Hence, *Holmesina* is considered a junior synonym of *Chlamytherium*, and the species *septentrionale* is referred to the latter genus. The differences reported by Sellards and by Simpson are minor and cannot be construed as indicating more than specific differences. They are quantitative in nature and represent a smaller range of variation than is



TEXT-FIG. *1*—Map showing localities for *Chlamytherium septentrionale* in relation to current distribution range of *Dasypus novemcinctus texanum*.

found in other edentate genera, including *Mylodon* (Stock, 1925) and *Dasypus* (Talmadge and Buchanan, 1954). It is quite possible that we are dealing with no more than intraspecific variations between North and South American subspecies which have not been sufficiently isolated, either vertically or horizontally, to produce separate species. The North American form, however, is here regarded as a distinct species until the type of the genus, *C. humboldtii*, can be examined.

The migration of *Chlamytherium* into North America probably followed a pattern similar to that of *Dasypus*. Evidence for this similarity can be observed in comparing the known localities for *C. septentrionale* in North America and the current range limits of the present armadillo. The presence of fossil *Dasypus* in late Pleistocene deposits of Texas, Oklahoma, Kansas, Missouri, and Florida (beyond the limits of recent *Dasypus*) indicates a former advance of this genus, similar to the range extension in which it is now involved.

The chlamytheres have been chosen, at one time or another, by Ameghino, Castellanos, and others as intermediates between the dasypods and glyptodonts. This stand was opposed by Simpson (1930), at which time he considered the group to be true armadillos. Heretofore, sufficient material has not been available for close comparison. The present specimen shows several characteristics which indicate a relationship with both the Dasypodidae and the Glyptodontidae, and an intermediate position for the group may be warranted. If so, the subfamily Chlamytheriinae should be elevated to family rank under the designation Chlamytheridae.

The specimen here described is a part of the University of Houston Collection, specimen No. H.C.T.4.

ACKNOWLEDGMENTS

Thanks are due to the following people for their assistance in the preparation of this work: Mrs. Florence H. Dawdy who located this specimen; Dr. Harold Tivey

and his assistants at the Jefferson Davis Hospital in Houston, who prepared the x-ray plates of this fossil; and Assistant Professor John T. Ferris at the University of Houston who did the photographic work included.

I am especially grateful to Dr. John A. Wilson at the University of Texas for releasing pertinent specimens for study, and to Dean H. J. Sawin at the University of Houston for his encouragement and careful scrutiny of this investigation.

CHLAMYTHERIUM SEPTENTRIONALE (Leidy)

Pl. 101, fig. 1–3; Pl. 102, fig. 1–3, Text-fig. 2–4

Glyptodon septentrionalis LEIDY, 1889, Acad. Nat. Sci. Philadelphia Proc., p. 97.

Chlamydotherium humboldtii LEIDY (*Not* LUND, 1838), 1889, Trans. Wagner Free Inst. Sci., vol. 2, p. 24–25; COPE, 1892, U. S. Geol. Survey, Bull. 84, p. 130; TROUESSART, 1904, Catalog. Mammalium. p. 812.

Chlamytherium humboldtii HAY (*Not* LUND, 1839), 1902, U. S. Geol. Survey, Bull. 179, p. 581–582.

Chlamytherium septentrionalis SELLARDS, 1915, Amer. Jour. Sci., 4th ser., vol. 40, p. 139–145; ——, 1916, Florida State Geol. Survey, 8th Annual Rept., p. 101–160; CAHN, 1922, Jour. Mamm., vol. 3, p. 22; HAY, 1923, Carnegie Inst. Publ., no. 322, p. 38; SIMPSON, 1928, Amer. Mus. Novitates, no. 328, p. 1–16; ——, 1929, Florida State Geol. Survey, 20th Annual Rept., p. 229–280; ——, 1930, Bull. Amer. Mus. Nat. Hist., vol. 54, pp. 561–599.

Holmesina septentrionalis SIMPSON, 1930, Amer. Mus. Novitates, no. 442, p. 1–9; HOLMES & SIMPSON, 1931, Bull. Amer. Mus. Nat. Hist., vol. 59, p. 402–405; CASTELLANOS, 1937, Publ. Fac. Cien., Univ. Nacional, Litoral., Ser., Tec.-cien Publ., vol. 8, p. 1–35; STOVALL & HIBBARD, 1948, Jour. Mamm., vol. 29, p. 420; HOFFSTETTER, 1952, Mém. Soc. Géol. France, new ser., no. 66, p. 119–121; ——, 1953, C. R., Soc. Géol. France, no. 6.

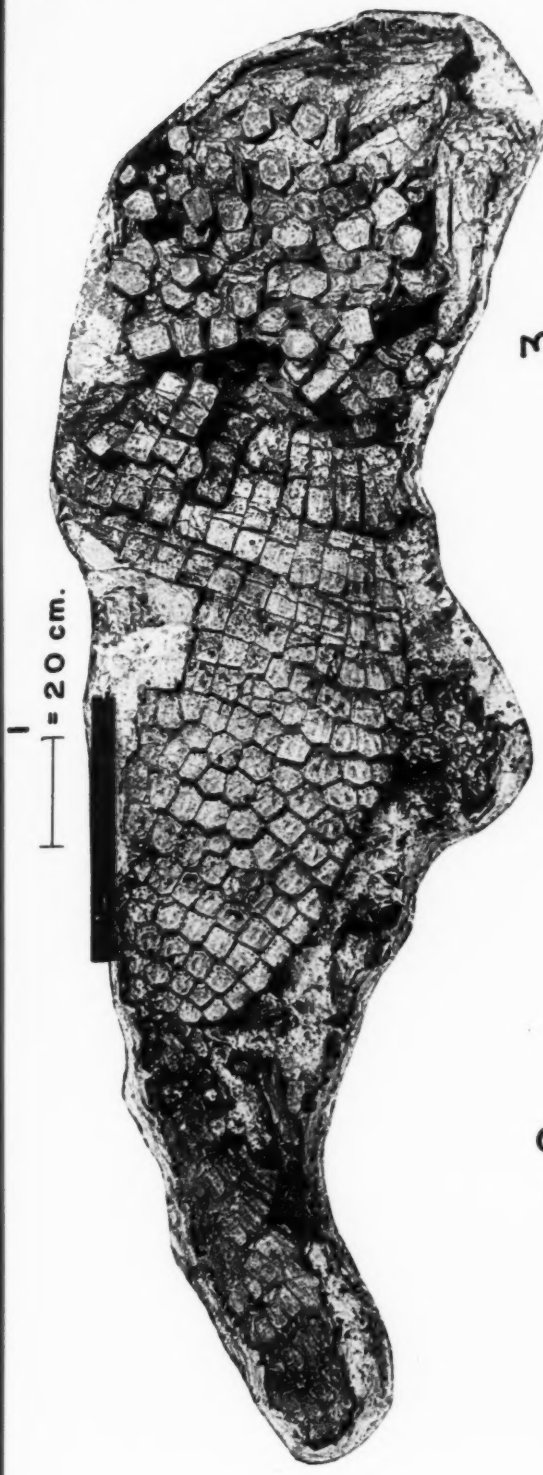
The specimen here described was recovered on March 9, 1955. It is approximately six feet long, eighteen inches wide, and is relatively well preserved. The right side of the animal is well represented; only a few bones from the left side were left after a drag-line operation at the site. The material from the left side shows a great amount of leaching but the right side shows little if any acid erosion. The specimen was removed by the usual plaster block technique and includes the following units: most of the right side of the carapace and tail, approximately 250 disarticulated dermal scutes, a complete skull with three scutes from the head shield, a partial atlas, and seven caudal vertebrae. Appendicular remains were articulated and included: a right humerus, a left and right radius, ulna and manus (some phalangeal and carpal units missing), a fragmentary right femur, right scapula, left humerus, and a poorly preserved right pes. Also included in the description are the following, borrowed from the University of Texas Collection: two thoracic vertebrae, an axis, three caudal vertebrae, a right femur, a right tibia, and a right humerus.

General Description.—The living animal, with its carapace divided into an anterior and posterior buckler by the presence of three bands of imbricating dermal scutes, its tail completely encased in a bony sheath, and a head shield also made up of dermal scutes, closely resembled current armadilos. Like many Pleistocene mammals, it was much larger than any of its present representatives, approximately three feet in height and six feet in length. The most striking differences between this animal and any living or fossil armadillo are in the skull. This deep and robustly built skull more closely resembles those in the glyptodonts. The bipartite teeth are intermediate between the tripartite teeth in the glyptodonts and the simple peg teeth of most armadilloid groups. The chlamytheres in general, of which *C. septentrionale* is no exception, possess a braincase more closely allied to those found in the glyptodonts than in the armadillos (personal communication: Bryan Patterson, Nov. 7, 1955). The remainder of the skeleton is very definitely armadilloid, with but few exceptions.

Carapace and Scutes.—The carapace is divided into an anterior and posterior area of articulated dermal units, in which there

EXPLANATION OF PLATE 101

FIG. *1–3—Chlamytherium septentrionale. 1*, Over-all view of specimen; *2*, x-ray of skull; and *3*, x-ray of left mandible.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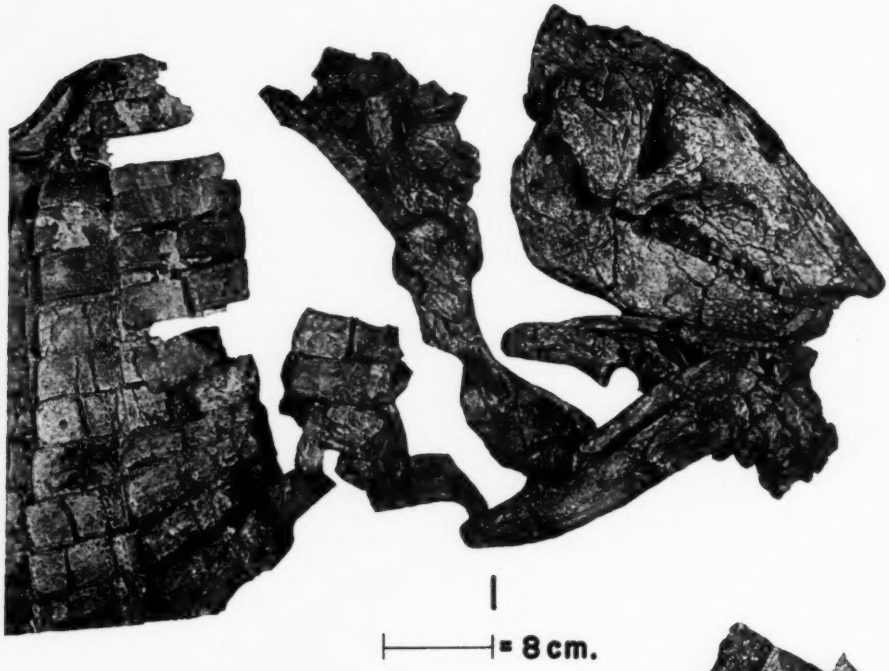

1

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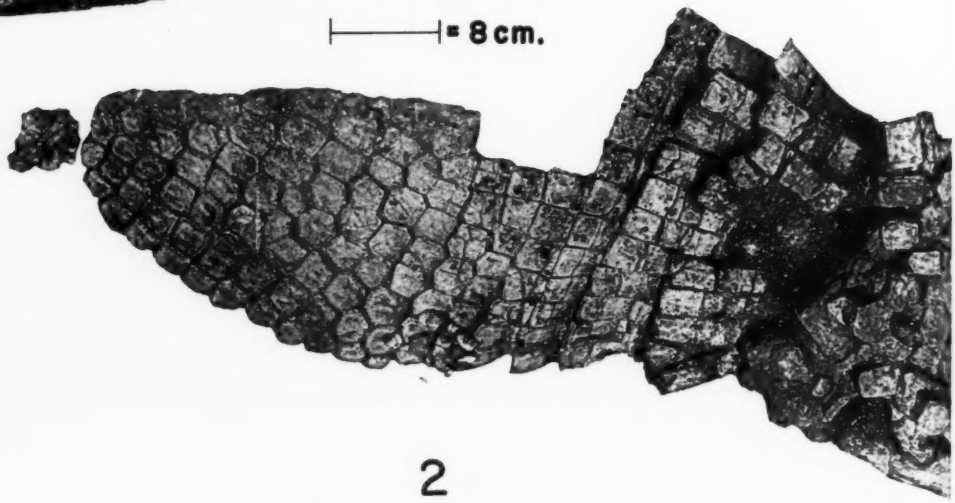

2

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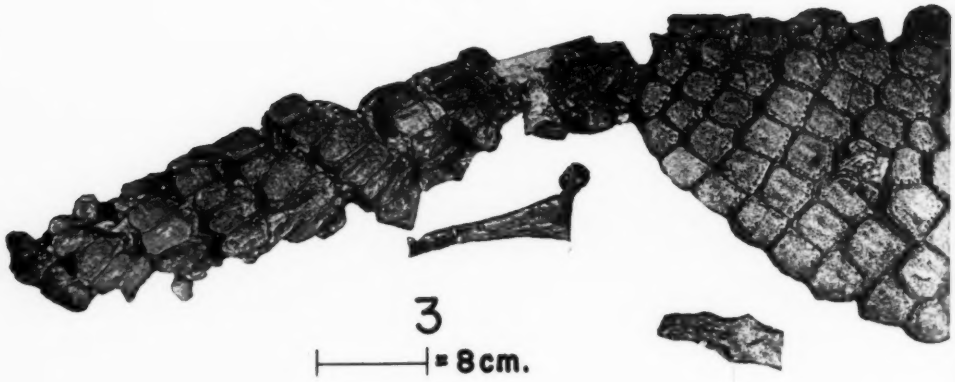

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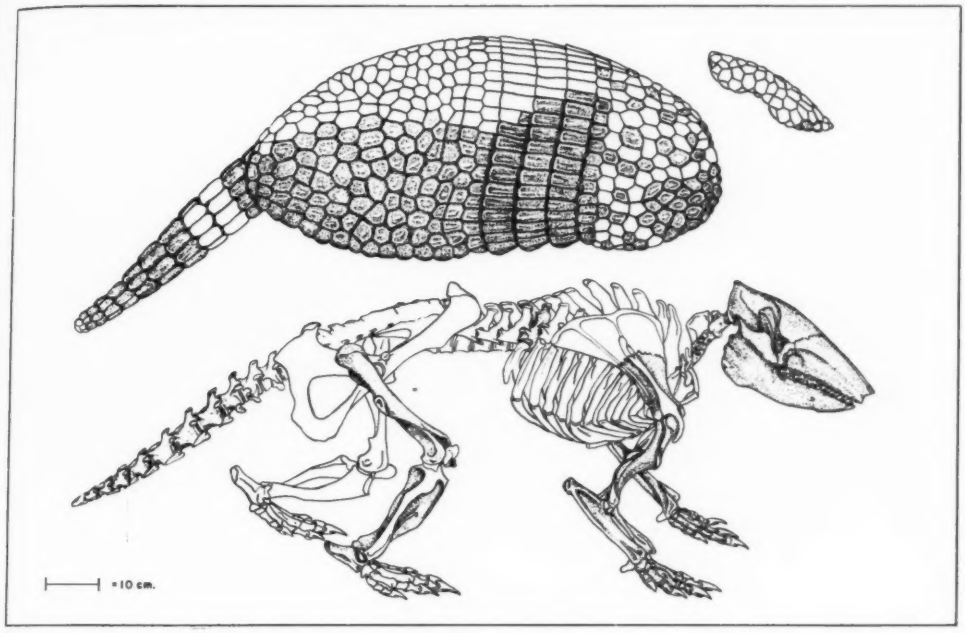


TEXT-FIG 2—Restoration of *Chlamytherium septentrionale.*

is limited movement. This division is accomplished by the presence of three bands of overriding or inbricating scutes in the lumbar region. These scutes are rectangular, between thirty and forty millimeters in width, and about a hundred millimeters in length. The anterior third of each scute is raised to form a smooth articular surface on which rides the complementary scute in the preceding band. The exposed surface is moderately pitted, has a raised area circumscribing its dimensions, and another in the center producing a keel-like ridge extending the length of each scute.

The anterior and posterior areas of the carapace consist of hexagonal or modified polygonal plates abutting to form a geometrical design, resembling a tiled floor. This design becomes more pronounced near the movable bands and is distorted toward the distal areas of the carapace. The plates show a wide variation both in size and shape but exhibit the same surface sculpturing as those of the movable bands. Plates bordering the carapace, however, have a nearly smooth surface. Their shape may be triangular, square, rectangular, pentagonal, or hexagonal. Their greatest diameter is from fifteen to forty-five millimeters, and the thickness is from five to eleven millimeters.

Little can be said concerning the scutes in the cephalic shield since only three of the bordering members of this structure could be identified from the many disarticulated plates recovered with this specimen. The three plates found were attached to the dorsal surface of the skull. These plates are small, irregular, and approximately two-thirds the thickness of the thinnest plate in the carapace. They show very little surface sculpturing.

The tail was encased in a sheath of

EXPLANATION OF PLATE 102

FIG. *1–3—Chlamytherium septentrionale. 1,* Anterior end; *2,* thoracic and abdominal section; and *3,* caudal end.

rounded, elongate, and closely articulated plates. Their length varies from approximately forty-five millimeters at the junction of the tail and body to about ten millimeters at the tip of the tail. The greatest width of the anterior plates is about twenty-five millimeters, and this width gradually decreases to about ten millimeters in succeeding plates. The tail sheath is considerably different from those found in recent armadillos and many fossil forms, in which the sheath consists of bands of imbricating plates throughout the length of the tail. In my specimen the tail sheath is formed by bands of abutting plates in which there is no imbricating movement. The external surfaces of the individual plates are somewhat different from those of the carapace. A median keel is present and is more distinct than in the carapace scutes, but it becomes progressively less distinct in the plates posteriorly. The raised area at the margin of the carapace plates is not present in the caudal plates.

The dermal scutes were probably covered with a layer of horn similar to that found on the plates of existing loricates. This material was not perserved with the specimen.

Skull.—The skull is complete except for the extreme anterior end of the nasal and premaxillary bones. It is deep, robust, and short-nosed when compared with other primitive or existing armadillos and more closely resembles the glyptodont skull. The zygomatic arch is complete, strongly built, and is extended downward at an angle of about forty-five degrees to a point just below the occlusion of the teeth. The lower ends of the two zygomatic processes meet to form the lower limit of the arch which resembles the long downward-projecting process of the jugal which is characteristic of the glyptodonts and sloths. The upper border of this arch, which is formed primarily by the squamosal process, forms a dorsally rounded contour approximately twenty-five millimeters in height. This structure is suggestive of the glyptodont skull in which the squamosal process forms a postorbital bar.

The palate is simple except at its posterior end where the sutures are so obscure that it is impossible to delineate the maxillae, palatines, or pterygoids. It is apparent, however, that the large, thick, descending processes, with their nipple-like protuberances, are pterygo-palatine structures. The palatines extend back over the vomers and most of the presphenoids, leaving exposed the rather large basioccipital. The auditory bullae are either incomplete or missing.

TABLE 1.—MEASUREMENTS (MM.) OF SKULL

Tip of snout to base of skull		290.0
Greatest width of base of skull		105.0
Width at jugal-squamosal suture		120.0
Greatest depth		100.0
Width at outer edge of condyles		70.0
Greatest diameter of foramen magnum		25.0
Average width of palate		40.0
Length of palate		220.0
	Left	Right
Length of tooth row	165.0	170.0
Greatest antero-posterior length of teeth		
P-1	10.0*	10.0*
P-2	13.0	11.0
P-3	16.0*	12.5
P-4	19.0*	15.5
M-1	21.5*	21.0
M-2	23.5	23.5
M-3	23.5	23.5*
M-4	22.5	20.0
M-5	13.0	13.5
Smallest diameter of teeth		
P-1	7.5*	7.5*
P-2	9.0	8.5
P-3	8.5	9.0*
P-4	8.5	8.5*
M-1	8.0	8.0*
M-2	7.5	8.0*
M-3	8.5	8.5*
M-4	7.5	7.5
M-5	6.5	6.5

* = Estimated measurements.
P = Premolar.
M = Molar.

The occipitals are broad, vertically orientated, and form a sharp occipital crest. There is little or no sagittal crest.

There are nine teeth in each maxilla; the first four are simple and peg-like, the last five are molariform. The premaxillary suture being indistinct, it is difficult to oriente correctly the first tooth. Simpson (1930, p. 5) reports that this tooth is included in the premaxilla, but, in the specimen here described, there are two structures resembling sutures. One of these "sutures" passes anterior to the first tooth and other posterior to it. Unless the specimen described by

Simpson has a definite maxillo-premaxillary suture, it is quite possible that the tooth in question is not located in the premaxilla. The palatal portion of the premaxillae, anterior to the first tooth, apparently functioned as a pad opposite a pair of centrally placed lower teeth.

Mandibles.—The mandibles are stout, articulated at the symphysis, and complete with the exception of their anterior tips and the first left tooth. The coronoid process is long, extending dorsally to within an inch of the top of the skull. It is inclined posteriorly from the vertical axis approximately fifteen degrees and possesses a distinct ridge extending diagonally forward and downward from the dorso-posterior tip to the anterior border. The ascending ramus is wide, making up approximately forty percent of the total length of the jaw, and it has on its inner face several distinct ridges. These ridges extend to the periphery and give this surface of the ramus a rather rugose appearance.

The mandibular foramen is located just below, and about ten millimeters behind, the last molar. The mental foramen is centrally placed opposite the third tooth.

There is no significant difference in size or shape between the upper and lower jaw teeth. In the molar series of both jaws, the occlusions are staggered so that the anterior half of the ninth upper tooth occludes with the posterior half of the ninth lower tooth. This condition is characteristic of the entire molar series except for the fourth upper tooth which is shortened, antero-posteriorly, so that it complements the anterior half of the fifth lower tooth only. Tooth one, two, and three of the upper jaw are immediately opposite tooth two, three and four in the lower jaw. Tooth number one in the lower jaw occludes with the anterior palatal portion of the premaxilla (Text-fig. 3). An interesting point is the relative height of the teeth in the molar series. Each lower molar, beginning with M-2, is slightly higher than its anterior neighbor, resulting in a "stair-step" arrangement. This condition is reversed in the upper molars. Although this may be the result of distortion in preservation, x-ray plates show no evidence of displacement in the alveoli or unexposed portions of the teeth (Pl. 101, fig. 3).

The molar teeth are deep-seated, rootless, enamelless, compressed laterally, and marked by furrows dividing each tooth into an anterior and posterior column. The occlusal surface is flat, smooth, and dumbbell- or figure-eight-shaped.

Vertebrae.—The vertebral column is represented by the right half of seven caudal units and the right half of the atlas. In the material collected at San Patricio County (see Localities in Texas, No. 7), an axis, two thoracic, and two caudal vertebrae were recovered along with several other bones belonging to this species. Since the other bones found in direct association with these vertebrae are identical to those recovered in this specimen; the posterior articular processes of the partial atlas in the specimen here described perfectly match the anterior articular process of the axis in the San Patricio material, the vertebrae from the above locality are included in this description.

Axis: The vertebrae are basically armadilloid and are similar to those of the recent armadillo. With the exception of the axis, the differences here reported are size variations only. In *Chlamytherium septentrionale*, the axis is fused with the succeeding three cervical vertebrae. It is a solid unit with one large transverse process on either side, a large spinous process extending back over the length of the unit, and foramina which appear to retain their original positions. In the present armadillo, *Dasypus novemcinctus texana*, fusion is less complete. The axis is united with the two succeeding cervical vertebrae only at their neural arches, zygopophyses, and spinous processes. The transverse processes are free, and between each centrum an intervertebral disc may be observed.

Atlas: Slightly more than the right half of the atlas was recovered in this specimen, and there is little difference between this unit and that of the recent armadillo. The dorsal tuberosity is less pronounced, but the remainder of the atlas is equal, proportionally, in size to that of *Dasypus*.

Thoracic Vertebrae: These vertebrae are of the typical xenarthral type, common to most edentates. There are two additional pairs of both the anterior and the posterior zygopophyses. The spinous process is con-

TABLE 2.—COMPARATIVE MEASUREMENTS (MM.) OF MANDIBLES

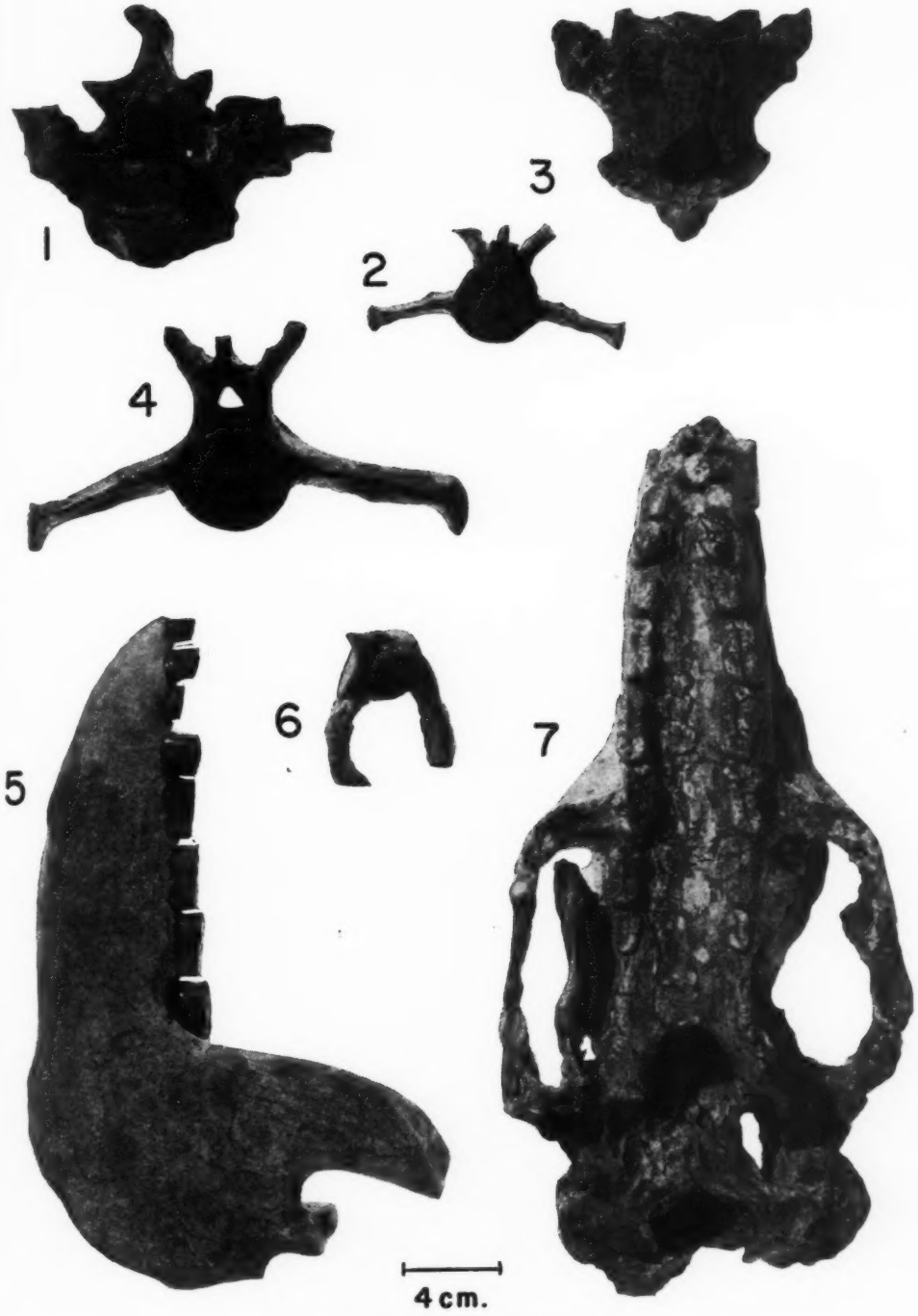
	C. humboldtii	*H. septentrionalis*	*C. septentrionale*	
	Left	Left	Left	Right
Greatest antero-posterior length	250.0*	240.0*	260.0*	260.0
Length of tooth row	180.0*	167.0*	170.0*	170.0
Length from mental prominence to angle of ramus	100.0	96.0	95.0	102.0
Anterior edge of condyle to posterior edge of coronoid	—	13.5	14.0	15.0
Length from coronoid to angle of ramus	—	—	155.0	160.0
Length of mandibular notch to angle of ramus	116.0	114.0	110.0	105.0
Width of ascending ramus at level of teeth	90.0	85.5	90.0*	94.0
Greatest diameter of condyle	—	—	29.0*	28.0
Smallest diameter of condyle	—	—	10.0	10.0*
Angle of coronoid	15°	15°	15°	15°
Depth of alveoli				
P-1	—	—	—	15.0*
P-2	—	—	25.0	25.0
P-3	—	—	33.0	33.0
P-4	—	—	37.0	38.0
M-1	—	—	45.0	43.0
M-2	—	—	50.0	53.0
M-3	—	—	53.0	53.0
M-4	—	—	47.0	50.0
M-5	—	—	25.0	35.0
Width of ramus at:				
P-2	22.0*	27.0	23.0	24.0
P-4	42.0*	20.0	39.0	40.0
M-2	52.0	52.5	50.0	50.0
M-4	52.0	54.0	51.0	53.0
Greatest antero-posterior length of teeth				
P-1	—	—	—	8.0*
P-2	8.5[a]	10.2	11.0	11.0
P-3	11.9[a]	12.2	12.5	12.2
P-4	18.4[a]	13.5	15.0	15.0
M-1	25.4[a]	19.6	22.0	22.5
M-2	25.4[a]	22.3	23.0	22.5
M-3	23.8[a]	22.4	23.0	23.0
M-4	20.0	19.1	20.5	20.0
M-5	14.0	13.0	13.0	13.0
Smallest diameter of teeth				
P-1	—	—	—	6.0*
P-2	5.1[a]	7.0	8.0	7.5
P-3	5.1[a]	7.0	9.0	8.0
P-4	7.5[a]	7.0	8.0	8.0
M-1	9.3[a]	7.0	8.0	9.0
M-2	8.5[a]	8.0	9.0	9.0
M-3	6.8[a]	7.0	8.0	8.0
M-4	5.0	7.0	7.5	8.0
M-5	4.0	6.0	7.0	7.0

* =Estimated measurements.

[a] =Alveolar measurements.

Measurements for *C. humboldtii* made from Lund, 1842, table 34, fig. 1–9. Other measurements made from mandible figured by Lund in 1841.

Greatest length of teeth for *H. septentrionalis* reported by Simpson, 1930, p. 7, smallest diameter taken from fig. 5, and other measurements from fig. 1 and 4.



EXPLANATION OF TEXT-FIG. *3*

FIG. *1–7—Chalmytherium septentrionale. 1*, Thoracic vertebra, Univ. Texas 30967–861; *2*, caudal vertebra, Univ. Texas 30967–1008; *3*, axis, Univ. Texas 30967–772; *4*, caudal vertebra, Univ. Texas 30967–905; *5*, left mandible; *6*, right half of atlas; and *7*, palatal view of skull.

TABLE 3.—MEASUREMENTS (MM.) OF AXIS

Greatest length	82.0
Greatest depth excluding spinous process	40.0
Width at posterior margin of transverse processes	98.0
Width at posterior margin of anterior articular processes	67.0

TABLE 4.—MEASUREMENTS (MM.) OF ATLAS

Greatest width	90.0*
Greatest length	33.0
Greatest depth	48.0*
Greatest diameter of posterior articular process	25.0
Smallest diameter of posterior articular process	15.0

*=Estimated measurements.

siderably shorter than in *Dasypus*, the angle produced by the transverse processes is much wider than in *Dasypus*, and the anterior zygopophyses-1 are not as widely separated as in *Dasypus*. The width and depth of the centrum is relatively smaller in this animal, but the length is proportionally the same as in the present armadillo. The greatest and smallest diameters of the vertebral foramen are much smaller and the tuberosities for muscle attachment are more pronounced in this animal. The remaining features of the vertebrae are comparable to those in *Dasypus*.

TABLE 5.—MEASUREMENTS (MM.) OF LAST THORACIC VERTEBRA

Depth from dorsal tip of spine to ventral margin of centrum	80.0
Width at outer margin of extra zygopophyseal articulations	100.0
Width at tips of transverse processes	120.0*
Length of spine at posterior zygopophyses	35.0
Antero-posterior length of centrum	30.0
Greatest diameter of centrum-posterior face	40.0
Greatest diameter of centrum-anterior face	35.0
Smallest diameter of centrum-posterior face	25.0
Smallest diameter of centrum-anterior face	22.0
Greatest diameter of vertebral foramen:	
Posterior margin	40.0
Anterior margin	25.0
Smallest diameter of vertebral foramen:	
Posterior margin	21.0
Anterior margin	20.0
Angle of transverse processes	120°

*=Estimated measurement.

Caudal Vertebrae: Of the caudal series, the right halves of seven units encased in a caudal shield of bony scutes are present in this specimen. It appears that the tail is nearly complete and twelve vertebrae are shown in the restoration drawing, but this number is conjectural. The two vertebrae from the University of Texas Collection are basically similar to those in *Dasypus* but show a number of relative size variations. The antero-posterior length of the centra decreases more rapidly in successive vertebrae, the spinous processes are more pronounced, and the transverse processes in the more posterior vertebrae are much longer than those of *Dasypus*. The greatest diameter of the vertebral foramen is relatively smaller, and the tips of the transverse processes are only slightly bifurcated.

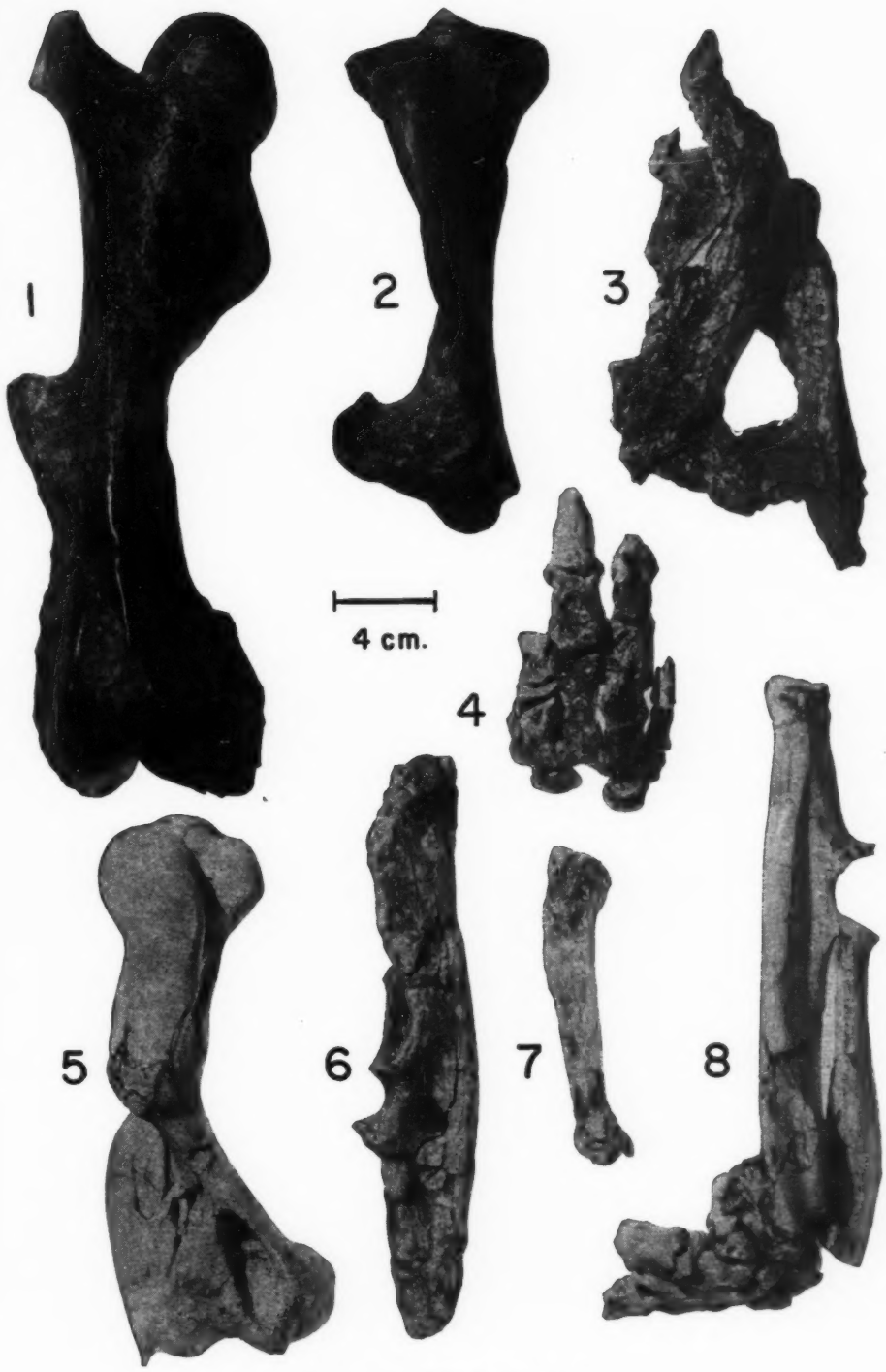
Scapula: The ventral half of the right scapula was preserved but is in such fragmentary condition that accurate measurements could not be made. The spine is less pronounced than in *Dasypus* but is similar in giving rise to a long downward-projecting acromion process at the lower end. The shape of the glenoid fossa is similar to that of the recent armadillo, and the coracoid process is somewhat larger. The scapula of this animal appears to be more heavily built than that of *Dasypus*, but it is very similar in over-all appearance.

Humerus: The right humerus is complete except for the lateral condyle, the head, and a few small fragments. Only the condylar

TABLE 6.—MEASUREMENTS (MM.) OF RIGHT HUMERUS

	H. septentrionalis	*C. septentrionale*
	Left	Right
Length from lateral tuberosity to lateral condyle	216.0	204.0
Width at proximal end	57.0	57.0
Width at distal end	81.0	80.0
Width of shaft at deltoid tuberosity	42.0	39.0
Width through condyles	51.0	51.0

Measurements of *H. septentrionalis* made from Simpson, 1930B, fig. 9, p. 580.



EXPLANATION OF TEXT-FIG. 4

FIG. *1–8—Chlamytherium septentrionale. 1*, Right femur, Univ. Texas 30967–870; *2*, right tibia, Univ. Texas 30967–1080; *3*, right scapula, outer surface; *4*, outer surface of left manus. *5*, anterior view of right humerus; *6*, inner surface of left ulna; *7*, inner surface of left radius; and *8*, outer surface of right radius, ulna, and manus.

portion of the left humerus is preserved. The restoration made of the right humerus is based on a nearly complete specimen from the University of Texas Collection and the part of the left humerus recovered with this specimen. The differences between the humerus of this animal and *Dasypus* are all relative size variations. The deltoid tuberosity is more pronounced, the neck is relatively thinner, the head is somewhat smaller, and the bone is slightly more twisted than in the recent armadillo. The *Dasypus* humerus is proportionately longer, the growth differential occurring in the length from the deltoid tuberosity to the lateral condyle. In general appearance the two humeri are very similar.

Radius: Both radii are preserved; although the left is somewhat fragmentary, the right is complete enough to show the major features of this bone. The radius is relatively shorter and heavier than in *Dasypus*, and the articular processes are slightly larger.

TABLE 7.—MEASUREMENTS (MM.) OF RIGHT RADIUS

Greatest length	130.0
Width at proximal end	32.0*
Width at distal end	37.0
Width at a point equidistant from ends	17.0

*=Estimated measurement.

Ulna: The ulnae are both present, the left in a somewhat fragmentary state, but the right is complete. As in the case of the radius, the ulna is relatively shorter and heavier than in the present armadillo. The olecranon is smaller, and the semilunar notch is placed more posteriorly. When observed from a dorsal or ventral view, the inward curve of the ulna is greater than in *Dasypus*.

TABLE 8.—MEASUREMENTS (MM.) OF ULNAE

	Left	Right
Greatest length	209.0*	204.0
Length from the anterior border of semilunar notch to distal end	103.0	100.0
Width across anterior half of semilunar notch	35.0	35.0*
Width of shaft just anterior to the semilunar notch	33.0	32.0*
Length of olecranon	35.0	35.0*

*=Estimated measurements.

Manus: Parts of the left and right manus were recovered with this specimen. A number of the phalangeal units of the right hand and a few of the carpal and phalangeal units of the left are missing. The manus is basically armadilloid and presents little variation, other than size, from that of *Dasypus*. The first and fifth finger, as well as the proximal phalanx of each finger, show great reduction in length. Each of the fingers is clawed, and the hand probably performed the same digging function that it does in the present armadillo.

Femur: The femur recovered with this specimen is very fragmentary consisting of only a portion of the shaft at the third trochanter. The dimensions, however, of this part are equal to those of the femur collected by the University of Texas, on which this description is based. The femur is identical to that figured by Lund (1841) for *Chlamytherium humboldtii*. It differs from the Dasypus femur in the following features: the greater trochanter is relatively shorter, the trochanteric fossa is shallower, and the lesser trochanter extends to the head. All other features are comparable to those of the recent armadillo.

TABLE 9.—MEASUREMENTS (MM.) OF FEMUR

	C. humboldtii	*C. septentrionale*
	Left	Right
Length from head to medial condyle	300.0	290.0*
Width at proximal end	100.0	95.0*
Width at distal end	88.0	86.0
Width at third trochanter	68.0	70.0

* =Estimated measurements.
Measurements of *C. humboldtii* made from Lund, 1841, table 13, fig. 2.

Tibia: Neither tibia was preserved with this specimen, and the following description is based on a right tibia collected by the University of Texas, with other bones previously mentioned. Little can be said in comparison of the articular processes of this bone and that of *Dasypus*, since in this specimen a large portion of the articular

processes have been restored. The tibia in most respects is very much like that of the recent armadillo, but it is considerably shorter and more heavily built. The crest is wider, and there is more twist in the tibia of this animal than in *Dasypus*.

Pes: A very fragmentary right pes was recovered, but because of its condition it cannot be described with any degree of accuracy.

Occurrence.—The locality of my specimen is on the south bank of Bray's Bayou at a point two hundred yards east of the Scott Street Bridge and approximately 12 feet below the top of the bank, in Houston, Harris County, Texas.

Other recorded localities for *Chlamytherium septentrionale* are indicated on the accompanying illustration (Text-fig. 1), and the data for these localities are given below. The current distribution range for *Dasypus novemcinctus texanum*, redrawn from Talmadge and Buchanan (1954), is included.

The fact that all the known localities for *Chlamytherium septentrionale* fall either within, or immediately adjacent to, the range of the current armadillo in North America is probably more than coincidental. A statement of explanation at this point would necessarily be conjectural.

Localities in Texas:

1. Bryan, Brazos County—A right lower jaw with teeth collected by Mr. W. A. Rounds at Pitts Bridge, about eight miles south and west of Bryan, at a point about a quarter of a mile below the bridge on the Brazos County side of the Brazos River. (Cahn, 1922, p. 23.)
2. Sinton, San Patricio County—A part of the right lower jaw with four teeth, collected by Dr. Mark Francis. Collected on the west bank of the Aransas River, about one mile north of the bridge on which the St. Louis & Brownsville Railroad crosses this river. It is also about 20 miles from Refugio, but nearer the town of Sinton. (Hay, 1926, p. 1.)
3. Midway, Madison County—A very fragmentary skull with part of both lower jaws, collected by Mr. Alex McCormick in 1913 and given to the Texas A. & M. College Museum. Collection was made on the Trinity River near Midway; no other data are available.
4. Rural Shade, Navarro County—Material was collected in the third terrace on the west side of the Trinity River, Crawford gravel pit, Loc. No. 31071. (Univ. Texas Bur. Eco. Geol. Rept., 1941.)
5. Trinidad, Henderson County—Material was collected two and a half miles northeast of Trinidad on the Leo Boatwright Farm, Loc. No. 30907. (Univ. Texas Bur. Eco. Geol. Rept., 1941.)
6. Berclair, Bee County—Remains taken from the left bluff of Medio Creek, about 13 miles downstream from Highway 96 crossing on the Fox Ranch. (Univ. Texas Bur. Eco. Geol. Rept., 1941.)
7. Ingleside, San Patricio County—Specimens recovered from Site No. 1, Loc. No. 30967, caliche pit on the W. E. Tedford Farm. From Ingleside go 0.2 mile from fork of road just south of Town, then turn left (east) and go 0.9 mile, then turn left (north) and go 0.3 mile to pit. Material included: a right femur, right humerus, right tibia, several vertebrae, and numerous dermal plates. (Univ. Texas Bur. Eco. Geol. Rept., 1941.)

Localities in Oklahoma:

1. Hydro, Caddo County—One dermal scute collected by Mr. W. E. Salter. The exact locality is not reported. (Stovall and Hibbard, 1948, p. 420.)

Localities in Florida:

1. Dunnellon, Marion County—Material taken from the Withlacoochee River, other collection data are not reported. (Sellards, 1916, p. 104. Hay, 1922, p. 38.)
2. Hillsboro River, Hillsboro County—Sellards reports that there are several dermal plates in the Jarman Collection of the Vanderbilt University. Other collection data are not reported. (Sellards, 1915, p. 143.)
3. Sarasota Bay, Sarasota County—One dermal plate, in the collection of the Wagner Free Institute of Philadelphia, was collected by Mr. Joseph Wilcox at White Beach. (Sellards, 1915, p. 143.)
4. Sarasota, Sarasota County—One dermal plate, in the American Museum of Natural History, was collected by Barnum Brown, eight miles southeast of Sarasota. (Hay, 1922, p. 38.)
5. Sarasota, Sarasota County—Specimens recovered by Mr. J. E. Moore, seven miles east of Sarasota at Phillippi Creek and Fruitville Ditch. (Simpson, 1929, p. 274.)
6. Seminole, Pinellas County—A left humerus, a left ulna, one tooth, and a dermal plate were collected by Mr. W. W. Holmes in the immediate vicinity of Seminole and is in the Walter W. Holmes Collection of the American Museum of Natural History. (Simpson, 1939, p. 580.)
7. Melbourne, Brevard County—Smithsonian and Amherst College, in a joint expedition, collected material from stratum No. 2 at this locality. The amount and exact locality for this material are not reported. (Simpson, 1929, p. 268.)
8. Lecanto, Citrus County—Mr. W. W. Holmes collected one dermal scute, a tooth, a limb bone, and foot bones, in Saber-tooth Cave on the property of Mr. D. J. Allen, one mile northwest of Lecanto. (Simpson, 1928, p. 1.)
9. Bradenton, Manatee County—Several der-

mal scutes, a left lower jaw, maxilla, and premaxilla were collected by Mr. W. W. Holmes, about one mile south of the business district and a quarter mile east of the Tamiami Trail, near Florida Avenue. (Simpson, 1930, p. 5.)

10. Vero, St. Lucie County—A part of the right side of the lower jaw, a part of the left side of same, a foot bone, and numerous dermal plates were collected from stratum No. 2. A lower jaw, tooth, and two dermal plates are described by Sellards from this same locality. Further locality data are not reported. (Sellards, 1915, p. 139–145.)
11. Arcadia, DeSoto County—Approximately thirty dermal plates collected from Peace Creek are in the Collection of the Wagner Free Institute of Philadelphia. (Hay, 1922, p. 38.)

Formation and Age.—Our specimen was taken from Pleistocene sediments, presumably of post-Mankato age. The Pleistocene in the Gulf Coast Plain is generally considered to consist of two sedimentary units, the Lissie sands and the Beaumont clays. This specimen, in situ, was resting at the bottom of the Beaumont, overlying the Lissie, in what appears to be an ancient distributary channel of the Brazos River.

Regarding the age of this animal, or the age of the sediments in which it was found, five to twenty thousand years should encompass the possibilities. Local stratigraphy and the condition of the specimen lead to the suspicion that this age is much closer to five than to twenty thousand years.

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JOURNAL OF PALEONTOLOGY, VOL. 31, NO. 4, P. 809–814, 2 TEXT-FIG., JULY 1957

PALEONTOLOGICAL NOTES

NIOBRARATEUTHIS BONNERI, A NEW GENUS AND SPECIES OF SQUID FROM THE NIOBRARA FORMATION OF KANSAS

HALSEY W. MILLER, JR.
Kansas State Geological Survey, Lawrence, Kansas

Fossil squids are rarely found in the Cretaceous rocks of Kansas. Although belemnites have been found in the Carlile shale and Niobrara formation, other types of dibranchiates are scarce and have been found only in the Niobrara formation.

Three genera assigned to the dibranchiate family Palaeololiginidae Naef have been described previously from North America. Two of these, *Tusoteuthis* Logan and *Phylloteuthis* Meek & Hayden, were discovered in the Niobrara formation. The third genus, *Ptiloteuthis* Gabb (1869) found in the Cretaceous of California, was described as a squid but subsequently has been shown by Rehn (1939) to be an insect wing.

ACKNOWLEDGMENTS

The writer is indebted to George F. Sternberg, curator of the Fort Hays Kansas State College Museum, for lending him the specimen here described and named. Thanks are expressed also to associates of the Kansas Geological Survey for aid in preparing the manuscript and to the director for permission to publish this paper.

The fossil designated as the holotype of the new species here described under the name *Niobrarateuthis bonneri* was found by M. C. Bonner of Leoti, Kansas, in the Smoky Hill chalk member of the Niobrara formation, exposed in the south ½, section 8, T. 15 S., R. 34 W., Logan County, Kansas. It was donated by him to the Fort Hays Kansas State College Museum. G. F. Sternberg (personal communication) found another specimen assigned to this species "about 22 miles southeast of Oakley [Logan County], Kansas, a half mile to the northeast of the old Maston house" in 1936. A third specimen was discovered by Mr. Sternberg "slightly higher up and ½ mile north" of the second specimen. Only the holotype was made available for study.

The holotype specimen consists of a complete but crushed gladius and an incomplete guard, the anterior end being broken away from the guard. The median keel also is partly broken away. However, the outline of the gladius is complete. Text-figure 2 shows restoration of an uncrushed individual. There is no indication of the presence of any soft parts, such as an ink sac.

Family PALAEOLOLIGINIDAE Naef, 1921

Three valid species of squids are referred to the family Palaeololiginidae (Roget, 1952, p. 741; Naef, 1922, p. 149–150). *Palaeololigo oblonga* Wagner is from the lithographic beds at Solenhofen, Bavaria and is the type species, and only known representative, of the type genus of the family. In addition to *Palaeololigo*, the family includes *Phylloteuthis subovata* Meek & Hayden from the Niobrara formation of South Dakota, and *Tusoteuthis longus* Logan from the Niobrara of Kansas.

The family Palaeololiginidae (Jurassic to Cretaceous) is placed by Naef in the superfamily Mesoteuthoidea (Naef, 1921) along with the families Trachyteuthidae (Jurassic to Cretaceous), Beloteuthidae (Jurassic to Cretaceous), and Celaenidae (Jurassic).

In the family Palaeololiginidae, the anterior end of the pen is narrow and forms a guard and the posterior end is enlarged to form a gladius that progressively spreads out laterally into the conus.

Niobrarateuthis is described as a new genus because the shape of its gladius differs materially from that of any previously described genus.

Genus NIOBRARATEUTHIS Miller, n. gen.
Type species: Niobrarateuthis bonneri, n. sp.

Description.—The gladius is elliptical, composed of corneus material, and the greatest width is near the anterior end. The

FIG. 1—*Niobrarateuthis bonneri*, n. gen., n. sp., dorsal view of the holotype, approximately one-sixth natural size. F.H.K.S.C. specimen 7959. The gladius is at the top.

guard is long and cylindrical, its posterior end bearing a median keel.

Remarks.—*Niobrarateuthis* differs from *Palaeololigo* Naef in that *Palaeololigo* has a relatively shorter guard, a more pointed gladius at the posterior end, and has a definite medial asymptote that extends along the guard. The surface markings on the gladii of the two genera are similar. *Niobrarateuthis* differs from *Tusoteuthis* Logan (1898, p. 97) in that *Tusoteuthis* has a lanceolate gladius and lacks a prominent keel. *Phylloteuthis* Meek & Hayden (1876, p. 505) differs from this new genus for it possesses a gladius that is more angular posteriorly, with the widest part of the guard in the posterior half and with a guard marked by parallel striations that pass obliquely outward and backward from the midrib.

NIOBRARATEUTHIS BONNERI, n. sp.
Text-fig. 1,2

The guard is 22 to 24 mm. in diameter; the anterior portion is broken off, and a length of 370 mm. remains. The keel is 115 mm. long and is continuous with the posterior portion of the guard. The surface of the guard is marked with parallel striations originating at the center line of the guard and inclined obliquely to the posterior, forming an angle of approximately 70 degrees to the center line. The interior of the guard appears to be composed of tubules oriented parallel to the main axis of the guard.

The gladius is 190 mm. long and 133 mm. wide at its greatest breadth. It is crushed, consisting of a mass of fragments that together retain the original outline. Faint concentric markings parallel to the outline are visible on the surface. However, it is not certain that these marks were present on the gladius of the living animal for they may be

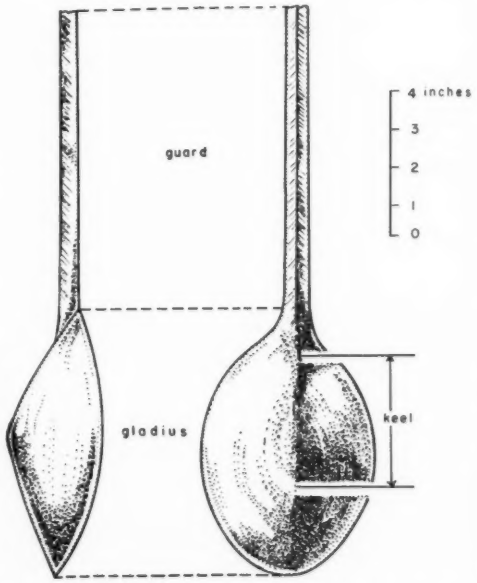

FIG. 2—*Niobraratheuthis bonneri*, n. gen., n. sp., restoration of gladius, anterior end of guard not restored.

brush strokes made during preparation when the specimen was varnished.

It is not possible to divide the gladius into conus, lateral part of conus, and lateral asymptote, because the fragmented condition of the fossil hides these features. No lateral plaque seems to be present. The broken upper portion of the keel stands about 20 mm. above the outer edge of the

gladius and presumably arched up over the keel. It is now crushed.

The species is named in honor of Mr. M. C. Bonner, who discovered the type specimen.

Repository.—The holotype is specimen 7959 of the Fort Hays Kansas State College Museum, Hays, Kansas.

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NOTES ON NEW GENERA OF PLIOMERIDAE (TRILOBITA)

HORACIO J. HARRINGTON
University of Kansas, Lawrence

The revision of all described species of trilobites assigned to the family Pliomeridae, undertaken for the Treatise on Invertebrate Paleontology, has led the writer to distinguish five new genera which are here briefly described.

Family PLIOMERIDAE Raymond, 1913
Subfamily PLIOMERINAE Raymond, 1913
Genus PLIOMERASPIS Harrington, n. gen.

Diagnosis.—Facial suture gonathoparian. Glabella wider than long, evenly expanded forward, with three pairs of lateral glabellar furrows; anterior furrows springing from anterolateral corners of glabella; frontal glabellar lobe large, with pair of oviform longitudinal depressions separated by low sagittal crest; eyes posterior; genal angles rounded. Middle Ordovician, China (Yunnan).

Type Species.—Pliomera martelli Reed (Reed, 1917, p. 55, pl. 8, fig. 15,16. Lectotype of species, here designated: cranidium illustrated in Reed, 1917, pl. 8, fig. 15).

Subfamily PROTOPLIOMEROPSINAE Hupé, 1955
Genus HINTZEIA Harrington, n. gen.

Diagnosis.—Glabella tapering forward, longer than wide; anterior lateral glabellar furrows located in front of anterolateral corners of glabella; eyes submedian to subanterior; genal angles rounded. Pygidium similar to that of *Protopliomerops* (as illustrated by *P. punctatus* Kobayashi), but with only five axial rings and five pairs of pleurae. Hypostoma pointed posteriorly. Lower Ordovician, North America.

Type species.—Protopliomerops aemula Hintze (Hintze, 1952, p. 206, pl. 22, fig. 9, 13–17).

Described species referable to Hintzeia, n. gen.—Protopliomerops celsaora Ross, *Protopliomerops firmimarginis* Hintze.

Genus KANOSHIA Harrington, n. gen.

Diagnosis.—Glabella parallel-sided; anterior lateral glabellar furrows springing from anterolateral corners of glabella; eyes subanterior; palpebrocular ridges well-developed; genal angles rounded. Pygidium of *Hintzeia* type. Hypostoma bifurcated, with very wide posterior border. Lower Ordovician, North America.

Type species.—Pseudomera kanoshensis Hintze (Hintze, 1952, p. 223, pl. 23, fig. 1–4).

Genus PROTOPLIOMERELLA Harrington, n. gen.

Diagnosis.—Glabella strongly tapering forward; anterior lateral glabellar furrows located well behind anterolateral corners of glabella; supplementary pair of faint de-

pressions in front of anterior furrows; eyes anterior, opposite anterior furrows; genal angles rounded. Pygidium with wide axis and narrow (tr.) pleural regions. Hypostoma strongly pointed posteriorly. Lower Ordovician, North America.

Type species.—Protopliomerops contracta Ross (Ross, 1951, p. 136, pl. 33, fig. 15–19, 22–32).

Genus ROSSASPIS Harrington, n. gen.

Diagnosis.—Glabella elliptical in outline; anterior lateral glabellar furrows springing from anterolateral corners of glabella; eyes anterior; genal angles bluntly spinose or pointed. Pygidium with comparatively narrow axis; pleurae outstretched, gently curved outward-backward, ending in free spines; terminal axial piece trapezoidal in outline, not wholly embraced by posterior pair of pleurae. Hypostoma rounded posteriorly. Lower Ordovician, North America, South America.

Type species.—Protopliomerops superciliosa Ross (Ross, 1915, p. 133, pl. 31, fig. 16–26; pl. 32, fig. 1–16; pl. 34, fig. 5–8,19).

Described species referable to Rossaspis, n. gen.—Protopliomerops rossi Harrington & Leanza.

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PALEONTOLOGY OF NORTHWESTERN VERMONT. VII. THE LOWER CAMBRIAN FAUNA (CORRECTIONS AND ADDENDUM)

ALAN B. SHAW
Shell Oil Company, Denver, Colorado

After the appearance of the summary of the Lower Cambrian fauna (Part V of this series) it was discovered that certain errors were, by oversight, permitted to remain in the published synonymies. In addition, certain references that were overlooked in the original compilation have been discovered. This paper is written to correct the typographical errors and to add the references to the synonymy.

Appearing almost coincidentally with the catalog was an important article on Lower Cambrian ptychopariid trilobites by Rasetti (1955). His conclusions modify the treatment of some species listed in the catalog, but since they require some discussion of the principles of taxonomy, these changes are left for a later date. Another important article, appearing since the publication of the general summary is Lochman's (1956) review of the fauna of the *Elliptocephala asaphoides* beds in New York. Comments on this article are also deferred until later.

I am indebted to Dr. Paul Tasch for acquainting me with his second note on the fauna of the Monkton quartzite (Tasch, 1949), which I had not seen in 1955. Inasmuch as Dr. C. H. Kindle has kindly loaned me all of the collections from the Monkton, and a review of the synonymy of the Monkton species is now in manuscript, references in Tasch's paper are omitted here.

Some references previously missed were found in Ruedemann (1947). A few references have also been added from Schuchert (1937), where they constitute original observations; Schuchert's copies of older lists (mainly those of Walcott) were purposely omitted from the catalog since Walcott's originals were included. Likewise, names of species given by Schuchert have been omitted wherever it has been impossible to be sure of their more modern taxonomic assignment. The species listed in various papers by Edson and Perkins in the Biennial Reports of the Vermont State Geologist have

been largely omitted because they are mainly copies of Walcott's data. In addition, reference to the catalog (Shaw, 1955) will give the current citation for nearly all of their specific names. Corrections and additions are made in the same alphabetical arrangement used in the catalog:

ANOMALOCARIS? EMMONSI (Walcott), 1886

Add to the synonymy:

Climacograptus? emmonsi Ruedemann, 1947, Geol. Soc. America Mem. 19, p. 53.

Genus BILLINGSASPIS Resser, 1935

Page 779, tenth line from bottom, first column. For "distinguished" read "distinguishes."

BILLINGSASPIS ADAMSII (Billings), 1861

Conocephalites Vulcanus LOGAN, 1863. For "ip." read "p."
Crepicephalus vulcanus HILLER, 1889, For "HILLER" read "MILLER"
Ptychoparia Adamsi MATTHEW, 1897. Should read p. 180–182,199.
Ptychoparella adamsi SCHUCHERT, 1937. Should read p. 1007,1028,1035.

Add to synonymy:

"*Ptychoparia adamsi*" SCHUCHERT, 1937, op. cit., p. 1022.

Page 780, eighth line from bottom, second column. For "(1947), p. 65." read "(1947, p. 65)"

BONNIA BUBARIS (Walcott), 1916

Page 781, fifth line from bottom, first column. For "Its" read "It".

BONNIA CAPITO (Walcott), 1916

Bonnia swantonensis RESSER, 1937. Third line. For "*Suppresses*" read "Suppresses".

DACTYLOIDITES EDSONI Ruedemann, 1934

Add to synonymy:

Dactyloidites edsoni Schuchert, 1937, Geol. Soc. Am. Bull., vol. 48, p. 1035.

Holotype.—For "40347a" read "40247a".

Page 784, second column, preceding discussion of *Dictyonema schucherti*, add: *Dawsonia parkeri* (see **Pagetides parkeri**)

DICTYONEMA SCHUCHERTI Ruedemann, 1933

Page 785, fifth line, first column. For "331" read "313".

EMMONSASPIS CAMBRENSIS (Walcott), 1891

Add to the synonymy:

Phyllograptus? cambrensis RUEDEMANN, 1947, Geol. Soc. America Mem. 19, p. 53.

HYOLITHES AMERICANUS Billings, 1871

Stratigraphic range.—Ninth line. For "bove" read "above".

HYOLITHES EDSONI (Schuchert, 1937?)

Hyolithes edsoni SCHUCHERT, 1937, Geol. Soc. America Bull., vol. 48, p. 1035.

This name is listed by Schuchert from the lower beds in Kelly Quarry (Loc. SA-C-1) about 150 feet above the base of the Parker. To date, I have not been able to find a description of it, and it may be a *nomen nudum.*

KOOTENIA MARCOUI (Whitfield), 1884

Add to synonymy:

Olenoides marcoui SCHUCHERT, 1937, Geol. Soc. Am. Bull., vol. 48, p. 1035.

Page 787, 34th line, first column. For "locality at" read "locality as".

Stratigraphic range.—Last line. For "*boucheri*" read "n. sp.". The species *K. boucheri* is described in Part VI of this series (Shaw, 1957) and the use of the name in Part V is a *nomen nudum.*

KUTORGINA CINGULATA (Billings), 1861

Tenth line of synonymy. For "OGAN" read "LOGAN". In addition, this line should be indented.

LINGULELLA FRANKLINENSIS (Walcott), 1912

Citation should read "1898", not "1912".
Page 789, 12th line, first column. Omit comma following "Hungerford".

NISUSIA TRANSVERSA (Walcott), 1886

Third line of synonymy. For "*Orhisina*" read "*Orthisina*".

OLENELLUS BRACHYCEPHALUS (Emmons), 1860

Page 792, seventh line, first column. Replace comma after "only" by a period.

Fourth line, third paragraph of *Diagnosis.* Omit comma before "Emmons".

OLENELLUS HERMANI Kindle & Tasch, 1948

Original citation should read "p. 136–137".

OLENELLUS THOMPSONI (Hall), 1859

Page 793, ninth line, first column. For "304" "340".

OLENELLUS VERMONTANUS (Hall), 1859

Olenellus vermontanus Billings, 1865. Third line. Replace comma by period.

Add to synonymy:

Mesonacis vermontanus SCHUCHERT, 1937, Geol. Soc. Am. Bull., vol. 48, p. 1035.

Page 794, first column.

Olenoides (*dorypyge*) *desiderata*. For (*dorypyge*) read (*Dorypyge*).

PAGETIDES PARKERI (Walcott), 1886

Add to the synonymy:

Dawsonia parkeri RESSER, 1937, Smithsonian Misc. Coll., vol. 95, no. 22, p. 9.

Microdiscus SCHUCHERT, 1937, Geol. Soc. Am. Bull., vol. 48, p. 1035.

PLANOLITES VIRGATUS (Hall), 1847

Last two entries in synonymy should be:

Planolites incipiens WALCOTT, 1890, U. S. Nat. Mus. Proc. for 1889, vol. 12, no. 763, p. 35.

Planolites virgatus WALCOTT, 1891, U. S. Geol. Survey 10th Ann. Rept., pt. 1, p. 602–603, pl. 61, fig. 5.

"PROTORTHIS" WINFI Walcott, 1905

For "WINFI" read "WINGI". For "brachiopod" read "(Brachiopod)".

SALTERELLA PULCHELLA Billings, 1861

Salterella pulchella SCHUCHERT, 1937, Geol. Soc. Am. Bull., vol. 48, p. 1023.

This citation mentions the species in the "Winooski" (*i.e.*, Dunham) marbles. It does not extend the range previously given (Shaw, 1955, p. 801).

STENOTHECA RUGOSA Schuchert, 1937
non Hall, 1847

Stenotheca rugosa SCHUCHERT, 1937, Geol. Soc. Am. Bull., vol. 48, p. 1034.

The citation given above was believed by Schuchert to refer to a Lower Cambrian species, but it does not. The locality was described by Shaw (1954, p. 1043) as Loc. SA-EC-1 and dated Middle Cambrian. In the faunal list for this location the species was referred to as *Helcionella* aff. *H. paupera*. A complete discussion is given in Part VI of this series (Shaw, 1957) under the name *Coreospira? raymondi*.

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SHAW, A. B., 1954, Lower and lower Middle Cambrian succession in north-western Vermont: Geol. Soc. America Bull., vol. 65, p. 1033–1046, 4 fig.

——, 1955, Paleontology of northwestern Vermont. V. The lower Cambrian Fauna: Jour. Paleont., vol. 29, p. 775–805, pl. 73–76.

——, 1957, Paleontology of northwestern Vermont. VI. The early Middle Cambrian Fauna: Jour. Paleont., vol. 31.

TASCH, PAUL, 1949, A new fossil locality in the Lower Cambrian Monkton formation of Vermont: Canadian Field-Naturalist, vol. 63, p. 210–211, 1 fig., 1 table.

NOTICE

On 30th January, 1957, at a meeting in London of palaeontologists and others interested in palaeontology, it was resolved to form a Palaeontological Association. An Inaugural Meeting was held on the 27th February when a constitution was adopted and the following elected as Council and Officers for 1957.

President: R. G. S. Hudson, Iraq Petroleum Co., London; Vice-Presidents: E. I. White, British Museum (Natural History), London, and N. F. Hughes, Sedgwick Museum, Cambridge; Secretary: F. Hodson, University, Reading; Treasurer: W. S. McKerrow, The University Museum, Oxford; Editor: W. H. C. Ramsbottom, Geological Survey, London. Other members of Council: F. W. Anderson, Geological Survey, London; T. Barnard, University College, London; O. M. B. Bulman, Sedgwick Museum, Cambridge; F. E. Eames, British Petroleum Co., London; G. F. Elliott, Iraq Petroleum Co., London; T. N. George, University, Glasgow; Dorothy H. Rayner, University, Leeds; P. C. Sylvester-Bradley, University, Sheffield; J. T. Temple, Birkbeck College, London; Gwyn Thomas, Imperial College of Science and Technology, London; T. S. Westoll, Kings College, Newcastle-on-Tyne; W. T. Whittard, University, Bristol; Alwyn Williams, Queens University, Belfast; and A. Wood, University College of Wales, Aberystwyth.

The Association, which seeks support from all who are interested in Palaeontology, plans to hold discussion-meetings in London and elsewhere. It is intended that the Association's activities should cover all aspects and branches of the subject. A Journal is being planned to commence publication in 1957. Membership may be obtained by paying an annual subscription of two guineas. (U. S. $5.88.)

ANNOUNCEMENT

S.E.P.M. PROGRAM FOR LOS ANGELES

MARCH 10–13, 1958

The A.A.P.G.–S.E.P.M. annual meeting for 1958 will be held in Los Angeles, March 10–13. All members of the Society are invited to submit papers for the program; papers from non-members are also solicited. However, non-members are required to have a member sponsor the paper. Persons submitting papers should send them directly to the appropriate program chairman.

W. H. Akers, Chairman Paleontology and Stratigraphy
The California Company
The California Company Building
New Orleans, Louisiana

C. M. Gilbert, Chairman Mineralogy and Sedimentary-Petrology
University of California
Berkeley, California

H. A. Ireland, Chairman Research Committee
University of Kansas
Lawrence, Kansas

The program is rapidly becoming full and it is suggested that if you desire to present a paper during this meeting that you notify the program chairman as soon as possible. November 1 is the deadline for submitting abstracts of papers presented during the technical programs and the symposium.

Silica in Sediments has been selected as the subject for the symposium for the Los Angeles meeting. The papers will be selected or requested according to a specific framework set up by the Research Committee. It is expected that the seven papers which will make up this symposium will be scheduled before June 1; however, if arrangements are delayed, an additional paper concerning some important aspect of silica in sediments may be included, if sent to the chairman of the Research Committee at once.

At the 1957 annual meeting, the council of the S.E.P.M. voted to inaugurate a "Best Paper Presented at the Annual Meeting Award." The best paper will be selected from the 1958 S.E.P.M. program and the award will be presented to the recipient at the business meeting the following year. The basis for selection will be (1) content, (2) organization, (3) quality of slides, and (4) presentation.

Plans are moving along at a rapid pace, and the indications are that we have a great convention in the making. We hope that you will take part in our program by presenting a stimulating and timely paper.

STUART A. LEVINSON
Vice-President S.E.P.M.
Chairman, Technical Program

JOURNAL OF PALEONTOLOGY, VOL. 31, NO. 4, P. 816–833, JULY 1957

SOCIETY RECORDS AND ACTIVITIES

REPORTS AND MINUTES OF THE THIRTY-FIRST ANNUAL MEETING OF THE SOCIETY OF ECONOMIC PALEONTOLOGISTS AND MINERALOGISTS

The thirty-first annual meeting of the Society of Economic Paleontologists and Mineralogists was held in Assembly Hall No. 1 of the Kiel Auditorium, St. Louis, Missouri, April 1–4, 1957, in conjunction with the annual meeting of The American Association of Petroleum Geologists.

The program consisted of a joint meeting with the A.A.P.G., with papers on Recent Sedimentation in Northern Gulf of Mexico being presented. The Society's program consisted of papers on Biostratigraphy; Sedimentary Mineralogy, Petrology, and Sedimentology; Geochemistry of Sedimentary Materials; and Paleontology and Stratigraphy.

The Presidential Address of the Society, "New Geological Horizons," was given by Robert R. Shrock at a joint session on Tuesday, April 2. (For complete address, please refer to A.A.P.G. *Bulletin*, Vol. 41, No. 7.)

Also at the joint session an "Honorary Membership Scroll" was presented to Henry V. Howe and it was announced that Philip H. Kuenen had been elected a Correspondent of the Society.

Born at Fulton, New York, on June 15, 1896, Henry V. Howe received a B.A. degree from the University of Oregon in 1916. He was a fellow at Yale University from 1916 to 1917, at the University of Oregon from 1918 to 1919, and at the University of California from 1919 to 1921. In 1922 he received a Ph.D. degree in geology from Stanford University.

Dr. Howe's experience includes: assistant professor, associate professor, and professor in the department of geology of Louisiana State University. He became the Director of the School of Geology in 1931 and from 1944 to 1949 was dean of the College of Arts and Sciences. In addition, from 1929 to 1927, he was consulting geologist for the Union Sulphur Company and from 1934 to 1940 was director of the research division of the Louisiana Geological Survey.

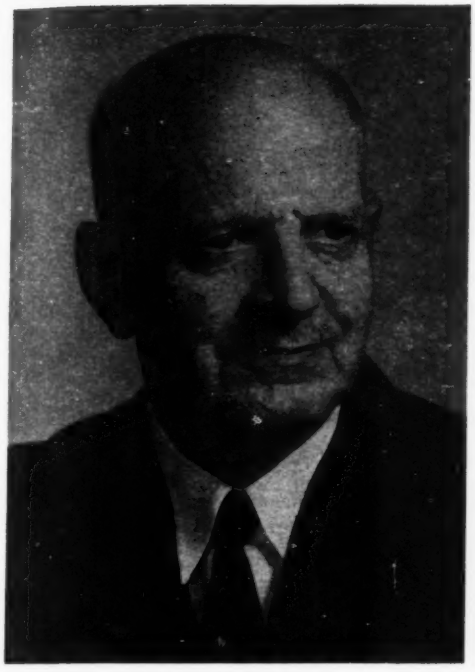
Howe's scientific affiliations are numerous, including The American Association of Petroleum Geologists, Geological Society of America, Paleontological Society, Geophysics Union, and Louisiana Academy of Science. He is a charter member of the S.E.P.M.; was president pro tempore, 1927–1928; secretary-treasurer from 1937–1939; and president from 1941–1942. Dr. Howe was very instrumental in helping to place the Society on a sound financial status during his two-year term as secretary-treasurer, and it was mainly due to his efforts that a satisfactory agreement with the Paleontological Society was reached for publishing the *Journal of Paleontology* jointly with that Society. Howe has served on numerous S.E.P.M. committees and has published many articles on paleontology in our *Journal of Paleontology* and on stratigraphy in the A.A.P.G. *Bulletin*.

Because of this honor, Dr. Howe will retain a life-time membership in the Society of Economic Paleontologists and Mineralogists and the *Journal of Paleontology* will be sent to him complimentary.

This year (1957) the Research Committee of the Society of Economic Paleontologists and Mineralogists nominated and the Council elected Philip Henry Kuenen of the Netherlands as a Correspondent, in recognition of the outstanding contributions that he has made in several fields of interest represented in our Society.

According to the constitution of the S.E.P.M. (Article 3, Section 5), "Correspondents shall be persons not resident in North America who have made distinctive contributions to paleontology, petrology, and stratigraphy that have application to the geology of petroleum."

In honoring Dr. Kuenen, who is professor of geology at the Geological Institute in Groningen, the S.E.P.M. takes special recognition of his contributions to sedimentation and stratigraphy. Although perhaps best known to American geologists for experimentation with sediment-laden water



HENRY V. HOWE
Elected to Honorary Membership

PHILIP H. KUENEN
Elected S.E.P.M. Correspondent

currents and application of his results to the interpretation of graded bedding and certain other primary structures in sedimentary deposits, Dr. Kuenen has always had a broad range of interest in the problems of the oceans and ocean bottoms. Papers listed in his bibliography concern such subjects as sediments of the deep seas, atolls, submarine canyons, pebble abrasion, ptygmatic folding, origin of volcanoes, relations between submarine topography and gravity field, and numerous articles on the scientific discoveries of the *Snellius Expedition* in the East Indian region.

As author of *Marine Geology* (John Wiley and Sons, New York, 1950), Dr. Kuenen brought together in masterly fashion a great mass of information on the geological aspects of oceans and ocean bottoms, and this outstanding book has become one of the standard works on the subject.

In a more recent book, *Realms of Water* (Cleaver Hume, London, 1955), he has again demonstrated unusual competence in bringing together a vast accumulation of scattered information dealing with a subject of great common interest.

In this imposing array of articles and books on a wide range of subjects, the petroleum geologist turns with deepest interest to Dr. Kuenen's many papers on sedimentary processes and structures published in various journals including the *Journal of Sedimentary Petrology* and the *Bulletin* of the A.A.P.G.; to his contributions to the 1950 (Chicago) S.E.P.M. Symposium on Turbidity Currents and his participation in the 1955 (New York) A.A.P.G. Symposium on the Late Quaternary Geology of Modern Sedimentary Basins; to his monographic contributions to the recent sedimentation in the Dutch East Indies; and to his sponsorship of recent sediment studies in the Orinoco delta area recently published by van Andel and others.

By virtue of his activities as stimulating teacher, ingenious experimentalist, imaginative investigator, and scholarly author, Dr. Kuenen has brought distinction to his country, to himself, and to his profession. In honoring him, the S.E.P.M. also honors itself in electing him Correspondent.

List of Publications of Ph. H. Kuenen 1925–1956

1. The Porphyry District of Lugano West of the Valganna. Leid. Geol. Med. I, 1, pp. 127–185, 1925 (Thesis).
2. Petrographic description of some igneous rocks from the Cordillera of South Mendoza in the Argentine. Leid. Geol. Med., II, 1, pp. 25–50, 1926.
3. Experiments on the formation of windworn pebbles. Leid. Geol. Med., III, 1, pp. 17–38, 1928.
4. Petrographic description of rock specimens from the Hunza Valley in the Karakoram. Leid. Geol. Med., III, 1, pp. 39–48, 1928.
5. +*B. G. Escher*. Experiments in connection with salt domes. Leid. Geol. Med., III, 3, pp. 151–182, 1929.
6. The origin of the Marwies Fold in the Santis Mountains. Eclog. Geol. Helv., 22, pp. 53–58, 1929.
7. Die Viermeter Lotröhre der "Snellius"-Expedition. Ann. Hydr. Mar. Meteor., pp. 93–97, 1932.
8. The formation of the atolls in the Toekang Besi Group by subsidence. Proc. Kon. Ned. Akad. Wet. Amsterdam, pp. 331–336, 1933.
9. Geology of coral reefs. Scientific results of the Snellius Expedition. Vol. V, Geological Results, part 2, 126 pp., 1933.
10. Relations between submarine topography and gravity field. Chapter VIII in: Gravity Expeditions at Sea, 1923–1932, Vol. II. The interpretation of the results by Vening Meinesz, pp. 183–194, 1934.
11. Experiments on the formation of volcanic cones. Leid. Geol. Med., VI, 2, pp. 99–118, 1934.
12. Bathymetrical results. Scient. Results of the Snellius Expedition. Vol. V, Geological Results. Geological Interpretation, 123 pp., 1935.
13. Contributions to the geology of the East Indies from the Snellius Expeditions. Part I. Volcanoes. Leid. Geol. Med., VII, 2, pp. 273–331, 1935.
14. The negative isostatic anomalies in the East Indies (With experiments) Leid. Geol. Med., VIII, 2, pp. 169–214, 1936.
15. Intrusion of cone-sheets. Geol. Mag., LXXIV, pp. 177–183, 1937.
16. Experiments in connection with Daly's hypothesis on the formation of submarine canyons. Leid. Geol. Med., VII, 2, pp. 327–351, 1937.
17. On the total amount of sedimentation in the deep-sea. Am. Jour. Sci., XXXIV, pp. 457–468, 1937.
18. +*Cath. Koomans*. On the differentiation of the Glen More Ringdyke, Mull, Geol. Mag., LXXV, pp. 145–160, 1938.
19. Observations and experiments on Ptygmatic folding. Bull. Comm. Géol. Finlande, 123, C.R.Soc. Géol. Finl., no. 12, pp. 11–28, 1938.
20. Density currents in connection with the problem of submarine canyons. Geol. Mag., LXXV, pp. 241–249, 1938.
21. +*L. U. de Sitter*. Experimental investigation into the mechanism of folding. Leid. Geol. Med., X, 2, pp. 217–240, 1938.
22. The cause of coarse deposits at the outer edge of the shelf. Geol. en Mijnb., pp. 36–39, 1939.
23. Quantitative estimations relating to eustatic movements. Geol. en Mijnb., pp. 194–201, 1939.
24. Sediments of the East Indian Archipelago. In: Recent Marine Sediments. Am. Ass. Petr. Geol., pp. 348–355, 1939; Reprinted by Soc. Econ. Pal. Min., 1955.
25. +*I.M. v.d. Vlerk*. Geheimschrift der Aarde. Utrecht, de Haan, 355 pp., 1941.
26. Major geological cycles. Proc. Kon. Ned. Ak. Wet. Amsterdam, XLIV, pp. 333–338, 1941.
27. Geochemical calculations concerning the total mass of sediments in the earth. Am. Jour. Sci., pp. 161–190, 239, 1941.
28. Kruistochten over de Indische diepzeebekkens. Den Haag, Leopold's Uitg. Mij., 220 pp., 1941.
29. Obilatoe, Kisar and Siboetoe. Geol. en Mijnb., pp. 81–90, 1942.
30. Pitted pebbles. Leid. Geol. Med., XIII, 1, pp. 189–201, 1942.
31. Collecting of the samples and some general aspects. Section I, part 3, Bottom Samples. Vol. V. Geological Results of the Snellius Expedition, pp. 1–46, 1943.
32. De Drentsche riviertjes en het meandervraagstuk. Verh. Geol. Mijnb. Gen., Geol. Ser., XIV, Gedenkboek P. Tesch, pp. 313–336, 1945.
33. Volcanic fissures, with examples from the East Indies. Geol. en Mijnb., pp. 17–25, 1945.
34. Rate and mass of deep-sea sedimentation. Am. Jour. Sci., 244, 563–572, 1945.
35. Two problems of marine geology: Atolls and Canyons. Verh. Kon. Ned. Ak. Wet. Amsterdam, Afd. Nat., 2e Sect. D1. XLIII, 3, pp. 1–69, 1947.
36. Water faceted boulders. Am. Jour. Sci., 245, pp. 779–783, 1947.
37. The formation of beach cusps. Jour. Geol., 56, pp. 34–40, 1948.
38. Influence of earth's rotation on ventilation currents of the Moluccan deep-sea basins. Proc. Kon. Ned. Ak. Wet. Amsterdam, Vol. LI, 4, pp. 417–426, 1948.
39. Slumping in the Carboniferous rocks of Pembrokeshire. Quart. Jour. Geol. Soc. London, 104, pp. 365–385, 1948.
40. Ambon and Haroekoe (Contrib. to the geology of the East Indies from the Snellius Exp., Part III). Verh. Ned. Geol. Mijnb. Gen., Geol. Ser., D1.XV, pp. 44–62, 1949.
41. Stereoscopic projection for demonstration in geology, geomorphology and other natural sciences. Jour. Geol., 58, pp. 49–54, 1950.

42. The formation of the continental terrace. The advancement of Science, Vol. VII, 25, pp. 76–80, 1950.
43. +*C. I. Migliorini.* Turbidity currents as a cause of graded bedding. Jour. Geol., 58, pp. 91–127, 1950.
44. Marine Geology, New York, John Wiley, 568 pp., 1950.
45. Turbidity currents of high density. Report XVIII Sess. Int. Geol. Congr., Part VIII, London 1948, pp. 44–52, 1950.
46. Mechanics of varve formation and the action of turbidity currents. Geol. Fören. Förhandl., 73, pp. 69–84, 1951.
47. An argument in favor of glacial control of coral reefs. Jour. Geol., 59, pp. 503–507, 1951.
48. Turbidity currents as the cause of glacial varves. Jour. Geol., 59, pp. 507–508, 1951.
49. Properties of turbidity currents of high density. Soc. Econ. Pal. Min. Sp. Publ., no. 2, pp. 14–33 1951. (Abst. A.A.P.G. Ann. Meeting, Chicago, 1950, pp. 36–37).
50. +*M. L. Natland.* Sedimentary history of the Ventura Basin, Calif., and the action of turbidity currents. Soc. Econ. Pal. Min., Sp. Publ., no. 2, pp. 76–107, 1951.
51. Slump structures in the Waitamata beds around Auckland. Trans. Roy. Soc. New Zealand, 78, pp. 467–475, 1950.
52. +*H. W. Menard.* Turbidity currents, graded and non-graded deposits. Jour. Sed. Petr., 22, pp. 83–96, 1952.
53. Estimated size of the Grand Banks turbidity current. Am. Jour. Sci., 250, pp. 874–884, 1952.
54. Significant features of graded bedding. Bull. Am. Ass. Petr. Geol., 37, pp. 1044–1066, 1953.
55. Graded bedding with observations on lower paleozoic rocks of Britain. Verh. Kon. Ned. Ak.Wet. Amsterdam, Afd. Nat., 1st reeks, D1. XX, 3, pp. 1–47, 1953.
56. +*A. Carozzi.* Turbidity currents and sliding in geosynclinal basins of the Alps. Jour. Geol., 61, pp. 363–373, 1953.
57. Origin and classification of submarine canyons. Bull. Geol. Soc. Am., 64, pp. 1295–1314, 1953.
58. Recent advances in deep-sea sedimentology. Proc. Roy. Soc., A, 222, pp. 289–295, 1954.
59. Eniwetok drilling results. Deep-sea Research, I, pp. 187–189, 1954.
60. Sea level and crustal warping. Geol. Soc. Am. , Spec. Paper, 62, pp. 193–203, 1955.
61. Realms of water, Cleaver Hume, London, 1955.
62. Recent sedimentation as a key to ancient deposits (*Abstract*), N. Y. Oil Finders Convention, A.A.P.G.-S.E.G.-S.E.P.M. Joint Meeting, Mar. 28–31, 1955, p. 28.
63. The difference between sliding and turbidity flow. Deep-sea Research, 3, pp. 134–139, 1956.
64. Experimental abrasion of pebbles. 2. Rolling by currents. Jour. Geol., 64, pp. 336–368, 1956.
65. Problematic origin of the Naples rocks around Ithaca, N. Y. Geol. en Mijnb., 18, pp. 277–283, 1956.
66. +*J. E. Sanders.* Sedimentation phenomena in Kulm and Flözleeres graywackes, Sauerland and Oberharz, Germany. Am. Jour. Sci., 254, pp. 649–671, 1956.
67. Experimental abrasion of pebbles. 1. Wet sand blasting. Leid. Geol. Med., 20, pp. 131–137, 1955.
68. +*E. ten Haaf.* Graded bedding in limestones. Proc. Kon. Ned. Ak. Wet. Amsterdam, Ser. B., pp. 314–317, 1956.

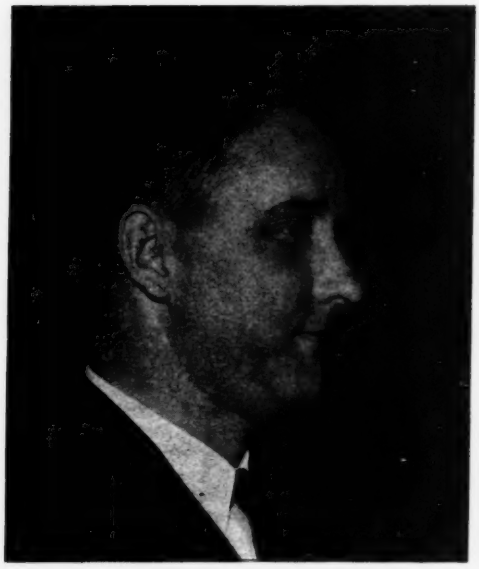
In addition to the above awards, Research Committee Chairman Curt Teichert, presented the Society's Award for the Best Paper for 1955 in the *Journal of Paleontology* to William R. Walton, for his paper entitled, "Ecology of Living Benthonic Foraminifera, Todos Santos Bay, Baja California," which appeared in the November issue, Volume 29, Number 6. Mr. Teichert also presented the award for the best paper for 1955 in the *Journal of Sedimentary Petrology* to Louis Field Dellwig, for his paper entitled, "Origin of the Salina Salt of Michigan," which appeared in the June issue, Volume 25, Number 2.

The Best Paper Awards are the third to be presented by the S.E.P.M. They consist of a certificate given to the author whose paper, appearing in the Journals during the second preceding year, is judged by the Research Committee to be the most outstanding contribution of the year.

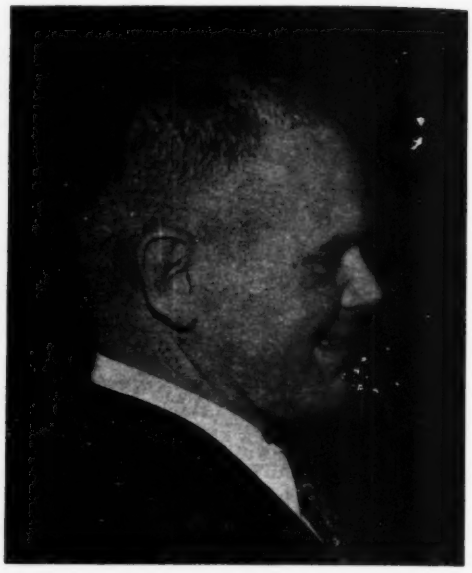
Born at Fort Worth, Texas, November 4, 1923, William R. Walton entered Amherst College, Amherst, Massachusetts, in the year 1946 and received a B.A. degree in geology from that institution in 1949. The next year he attended Harvard University where he specialized in sedimentation. In 1950 Mr. Walton transferred to the University of California's Scripps Institution of Oceanography where he majored in oceanography and received both his M.S. degree (1952) and Ph.D. degree (1953).

In 1953 Dr. Walton accepted a position with the Gulf Research and Development Company, Houston, Texas, the nature of his work being recent ecology, and in the summer of 1956 was transferred by that company to its Pittsburgh office.

Mr. Walton's publications, in addition to his recent article in the *Journal of Paleontol-*



WILLIAM R. WALTON
BEST PAPER AWARD, 1955
Journal of Paleontology



LOUIS F. DELLWIG
BEST PAPER AWARD, 1955
Journal of Sedimentary Petrology

ogy, include, "Ecology of Marsh and Bay Foraminifera, Barnstable, Massachusetts," *American Journal of Science*, Volume 248, April, 1950 (with Fred B. Phleger) and "Techniques for the Recognition of Living Foraminifera," Cushman Foundation for Foraminiferal Research, Volume III, Part 2.

Dr. Walton is a member of Sigma Xi, and in June, 1954, he became an associate member of the Society of Economic Paleontologists and Mineralogists.

Louis Field Dellwig was born February 13, 1922, in Washington, D. C. He entered Lehigh University in the fall of 1939 and obtained both his B.A. and M.S. degrees from that institution in 1943 and 1948, respectively. Later he transferred to the University of Michigan from which he was granted a Ph.D. degree in geology in February, 1954.

During the summers of 1948 and 1949 Mr. Dellwig was engaged in pegmatite studies for the U. S. Geological Survey and from June, 1950, until January, 1952, he was engaged in uranium and thorium investigation for the U.S.G.S. From September, 1951, until June, 1953, Mr. Dellwig was an instructor in general, historical, and field geology at the University of Michigan, and in 1953 he accepted a position with the University of Kansas geology department as an assistant professor of structural geology.

Dr. Dellwig's scientific affiliations, in addition to his membership in the S.E.P.M., include the Seismological Society of America, American Geophysical Union, Geological Society of America, and The American Association of Petroleum Geologists.

In addition to his recent paper in the *Journal of Sedimentary Petrology*, Mr. Dellwig has published an article in the *American Mineralogist*, Volume 38, entitled, "Hopper Crystals of Halite in the Salina of Michigan." Also, Mr. Dellwig is a co-author of "Thorium Investigations, 1950–1952, Wet Mountains, Colorado," which appeared in the U. S. Geological Survey Circular 290.

ANNUAL BUSINESS MEETING

The annual business session of the Society was called to order at 4:00 P.M., Tuesday, April 2, by Robert R. Shrock, president, who introduced the officers for the new year as follows: President, R. V. Hollingsworth; Vice-President, Stuart A. Levinson; Secretary-Treasurer, Samuel P. Ellison, Jr.; Editor of the *Journal of Paleontology*, M. L.

Thompson; and Editor of the *Journal of Sedimentary Petrology*, Jack L. Hough. Shrock remains a member of the council as Past-President.

It was moved, seconded, and carried that the minutes of the 1956 meeting be approved as published in the July, 1956, *Journal of Paleontology* and the June, 1956, *Journal of Sedimentary Petrology*.

The following reports were given:

1. *Report of the Editor of the Journal of Paleontology* (*W. M. Furnish*).—Volume 30 of the *Journal of Paleontology*, issued in conjunction with the Paleontological Society, contains a total of 1,394 pages and 146 plates. There are 94 titles plus paleontological notes, reviews, and an author-subject index. Society records, notices, and abstracts of meetings are also included.

This volume represents an increase of 210 pages and 38 plates over the preceding one; it exceeds a 10-year average by about 250 pages and 40 plates. That portion of Volume 30 sponsored by the S.E.P.M. (March, July, and November issues), totals 584 pages and 54 collotype plates. These items represent an increase of 90 pages of text and 18 plates over that in corresponding issues of the previous years; and about 70% and 60%, respectively, of Paleontological Society totals in Volume 30. Most manuscripts have been published within nine months after being received, and there has been a rather uniform supply on hand to maintain this margin.

In the S.E.P.M. issues of Volume 30, there are 29 papers, exclusive of notes. Four were contributed by authors outside North

OFFICERS OF THE SOCIETY OF ECONOMIC PALEONTOLOGISTS AND MINERALOGISTS, 1957–1958.

Seated, left to right, M. L. Thompson, Editor, *Journal of Paleontology;* R. V. Hollingsworth, President; S. P. Ellison, Jr., Secretary-Treasurer; standing, left to right, J. L. Hough, Editor, *Journal of Sedimentary Petrology;* R. R. Shrock, Past-President; S. A. Levinson, Vice-President.

America. A variety of subjects are treated, but the majority deals with systematic descriptions of fossil animals. Emphasis has been placed upon the descriptive and applied aspects of microfossils—22 of the 29 titles and two-thirds of the total text. Studies are about evenly divided between Paleozoic and post-Paleozoic. The 11 reviews of current literature and 15 notes published averaged 2–3 pages of text.

The State University of Iowa contributed editorial and financial assistance.

2. *Report of the Editor of the Journal of Sedimentary Petrology* (*Jack L. Hough*).—The *Journal of Sedimentary Petrology* was published in 1956 as Volume 26, Numbers 1 through 4. The total number of pages was 386, or an average of 96.5 pages per number. Nineteen hundred copies of the first number were printed, and twenty-one hundred copies of the last three numbers were printed. During the past 8 years the total cost of printing has increased by approximately 2.5 times; the printing cost per volume has remained nearly constant, at approximately $3.00; and the printing cost per page has decreased to $0.00808, the lowest figure in the history of the Journal. Due to a substantial increase in printing rates, which became effective with the December number of the *Journal*, the *Journal* showed a small net loss after deduction of its share of headquarters office expenses. The *Journal* will show a very substantial loss in 1957 unless the subscription rate and dues are increased.

The contents of Volume 26 include 28 technical articles, 8 notes, 3 discussions, 1 review, 1 page of errata, and 9 pages of index, totalling 301 pages of technical material. Data concerning the Society of Economic Paleontologists and Mineralogists, including the membership list, announcement and program of annual meeting, minutes, and abstracts of papers given at the annual meeting, filled 70 pages.

The distribution of articles, notes, and discussions, according to national origin was as follows: United States, 36; Australia, 1; England, 1; and Switzerland, 1.

The backlog of manuscripts has continued to increase, so that a further increase in size of the *Journal* is desirable. An increase in the subscription rate will be necessary to provide for any expansion.

As in the past seven years, the University of Illinois has provided a part-time editorial assistant.

3. *Report of the Secretary-Treasurer* (*Samuel P. Ellison, Jr.*).—

MEMBERSHIP, MAILING, AND JOURNAL STATISTICS

	Dec. 31, 1956	*Dec. 31, 1955*	*Dec. 31, 1954*
1. S.E.P.M. Membership:			
Active Members	990	895	751
Associates	292	285	310
Correspondents	5	5	5
Honorary Members	3	3	1
	1,290	1,188	1,067
2. *Journal of Paleontology* Mailing List:			
S.E.P.M. Active & Honorary Members	509	485	434
S.E.P.M. Associates	150	155	165
Subscribers	810	722	684
P.S. Members	624	610	612
	2,093	1,972	1,895
3. *Jour. of Sedimentary Petrology* Mailing List:			
S.E.P.M. Active & Honorary Members	677	607	483
S.E.P.M. Associates	184	171	183
S.E.P.M. Correspondents	5	5	5
S.E.P.M. Subscribers	890	806	740
	1,756	1,584	1,411
4. Edition of *Journal of Paleontology*	2,400	2,200	2,200
5. Edition of *Journal of Sed. Petrology*	2,100	1,900	1,700
6. Number of Pages, *Journal of Paleontology*	1,394	1,084	888
7. Number of Plates, *Journal of Paleontology*	146	108	100
8. Number of Pages, *Journal of Sed. Petrology*	386	317	298
9. New Members	137	161	133
10. Transfers to Active Membership	41	47	44
11. Members and associates dropped for non-payment of dues, 1/1/57.	17	16	28

FINANCIAL STATEMENT BY AUTHOR YOUNG & COMPANY

SOCIETY OF ECONOMIC PALEONTOLOGISTS AND MINERALOGISTS
BALANCE SHEET, DECEMBER 31, 1956

ASSETS	*Total*	*General Fund*	*Publication Fund*
CURRENT ASSETS:			
Cash	$26,869.14	$19,023.10	$ 7,846.04
Savings account	2,667.49	2,667.49	—
Accounts receivable	826.69	785.94	40.75
Total current assets	$30,363.32	$22,476.53	$ 7,886.79
PUBLICATIONS:			
Journal of Paleontology:			
Issues prior to 1956—13,310 journals at 50¢ each (2,095 complete volumes)	$ 6,655.00	$ 6,655.00	$ —
Issues 1 to 6 of 1956—963 journals, at cost	2,075.02	2,075.02	—
Reprints in 1948, Volume 1, 1927—706 volumes, at cost	1,539.83	1,539.83	—
Journal of Sedimentary Petrology:			
Issues prior to 1956—2,477 journals at 50¢ each (710 complete volumes)	1,235.50	1,235.50	—
Issues 1 to 4 of 1956—1,345 journals, at cost	1,154.68	1,154.68	—
Special publications:			
Turbidity Currents, 374 issues, at cost	319.81	—	319.81
Recent Marine Sediments, 845 issues, at cost	1,743.66	—	1,743.66
Finding Ancient Shorelines, 481 issues, at cost	840.69	—	840.69
Total publications	$15,564.19	$12,660.03	$ 2,904.16
FURNITURE AND FIXTURES (less reserve, $1,793.84)	$ 1.00	$ 1.00	$ —
DEFERRED CHARGES	$ 1,918.57	$ 277.11	$ 1,641.46
	$47,847.08	$35,414.67	$12,432.41
LIABILITIES AND SURPLUS			
CURRENT LIABILITIES:			
Accounts payable	$ 5,120.27	$ 5,120.27	$ —
Amount payable to Paleontological Society	3,367.79	3,367.79	—
Accrued printer's charges	1,347.30	—	1,347.30
Total current liabilities	$ 9,835.36	$ 8,488.06	$ 1,347.30
DEFERRED CREDITS:			
Subscriptions to journals—net of portion to be received by Paleontological Society	$ 6,921.16	$ 6,921.16	$ —
Subscriptions to special publications	4,968.30	—	4,968.30
Membership dues for 1957 and 1958	6,770.00	6,770.00	—
Total deferred credits	$18,659.46	$13,691.16	$ 4,968.30
SURPLUS, PER ACCOMPANYING STATEMENT	$19,352.26	$13,235.45	$ 6,116.81
	$47,847.08	$35,414.67	$12,432.41

SOCIETY OF ECONOMIC PALEONTOLOGISTS AND MINERALOGISTS
STATEMENT OF INCOME AND SURPLUS
YEAR ENDED DECEMBER 31, 1956

	Total	*General Fund*	*Publication Fund*
INCOME:			
Membership dues and subscriptions:			
Journals of Paleontology and Sedimentary Petrology	$ 3,963.00	$ 3,963.00	$ —
Journal of Paleontology	14,204.65	14,204.65	—
Journal of Sedimentary Petrology	7,907.97	7,907.97	—
	$26,075.62	$26,075.62	$ —
Sales of special publications:			
Turbidity Currents	$ 314.55	$ —	$ 314.55
Recent Marine Sediments	1,383.00	—	1,383.00
Finding Ancient Shorelines	3,911.65	—	3,911.65
	$ 5,609.20	$ —	$5,609.20
Sales of back numbers:			
Journal of Paleontology, Volumes 1 to 30	$ 4,309.94	$ 4,309.94	$ —
Journal of Sedimentary Petrology	714.20	714.20	—
	$ 5,024.14	$ 5,024.14	$ —
Sales of plates	$ 417.03	$ 417.03	$ —
Advertising	$ 436.25	$ 436.25	$ —
Convention income	$ 471.77	$ 471.77	$ —
Donation from The American Association of Petroleum Geologists	$ 1,520.00	$ 1,520.00	$ —
Miscellaneous	307.71	307.71	—
	$39,861.72	$34,252.52	$5,609.20
Less: Portion of 1956 income accrued to Paleontological Society	2,825.78	2,825.78	—
	$37,035.94	$31,426.74	$5,609.20
COSTS AND EXPENSES:			
Cost of printing:			
Journal of Paleontology	$13,247.27	$13,247.27	$ —
Journal of Sedimentary Petrology	6,726.47	6,726.47	—
Finding Ancient Shorelines	3,453.52	—	3,453.52
	$23,427.26	$19,973.74	$3,453.52
Expenses:			
Clerical salaries	$ 7,203.75	$ 7,203.75	$ —
Office supplies	588.42	588.42	—
Postage and express	1,855.77	1,743.57	112.20
Office rent	1,500.00	1,500.00	—
Telephone	38.84	38.84	—
Audit fee	200.00	200.00	—
Payroll taxes	148.97	148.97	—
Miscellaneous	1,104.53	866.51	238.02
	$12,640.28	$12,290.06	$ 350.22
Adjustment for increase in inventory of publications	$ (255.31)	$ (199.89)	$ (55.42)
	$35,812.23	$32,063.91	$3,748.32
NET INCOME (LOSS)	$ 1,223.71	$ (637.17)	$1,860.88
SURPLUS AT DECEMBER 31, 1955	18,128.55	13,872.62	4,255.93
SURPLUS AT DECEMBER 31, 1956	$19,352.26	$13,235.45	$6,116.81

4. *Report of the Research Committee (Curt Teichert, Chairman).*—Between April, 1956, and April, 1957, the membership of this committee was as follows: O. L. Bandy, V. E. Barnes, W. C. Bell, R. V. Hollingsworth, D. L. Inman, S. A. Levinson, A. R. Loeblich, H. H. Murray, R. H. Nanz, W. J. Plumley, R. R. Shrock, R. A. Siever, L. L. Sloss, F. B. Van Houten, and Curt Teichert.

At the annual meeting in 1955 the council accepted a proposal from the committee to direct the chairman to organize a symposium on biostratigraphy to be held at the 1957 meeting. The response to the plan of the symposium was good and the number of papers offered exceeded the number that could be accepted. In the selection of papers preference was given to contributions demonstrating applicability of study of evolutionary lineages to biostratigraphy and usefulness of planktonic faunas in correlation. Authors of papers were V. Standish Mallory and H. E. Wheeler, Christina L. Balk and J. L. Wilson, T. A. Amsden, M. K. Elias, D. A. Myers, W. C. Hoffmeister and L. R. Wilson, A. R. Loeblich and Helen Tappan. Fossil groups discussed included foraminifera, bryozoa, trilobites, and plant microfossils, and ranged in age from Cambrian to Eocene.

The Research Committee recommended the following persons as recipients for the Best Paper Awards: W. R. Walton for the award for the best paper in the *Journal of Paleontology* for 1955 for the paper entitled, "Ecology of Living Benthonic Foraminifera, Todos Santos Bay, Baja California," and Louis F. Dellwig for the award for the best paper in the *Journal of Sedimentary Petrology* for 1955 for the paper entitled, "Origin of the Salina Salt of Michigan." The recipients of the awards were presented to the president, R. R. Shrock, by Curt Teichert at the joint session of A.A.P.G. and S.E.P.M at St. Louis.

The Research Committee presented to the council by unanimous vote the nomination of Henry V. Howe as an Honorary Member of the Society. The council approved and the presentation was made at the annual meeting by Marcus A. Hanna. The Committee also presented to the council by unanimous vote the nomination of Philip H. Kuenen as Correspondent of the Society. The council approved and presentation was made by R. R. Shrock at the annual meeting.

The Research Committee held a meeting at St. Louis on April 1, 1957, at 10:30 A.M. Those present were: W. C. Bell, R. A. Siever, W. J. Plumley, L. L. Sloss, R. R. Shrock, R. V. Hollingsworth, Stuart A. Levinson, A. R. Loeblich, Haydn H. Murray, H. A. Ireland, Grover Murray, W. A. Akers, and W. D. Pye. The Committee adopted a resolution to recommend to the council that authors of symposia papers should be requested to present final publishable manuscripts of their papers on September 15 of the year in which the symposium is held.

The Committee selected "Silica in Sediments" as the topic for the Research Committee Symposium in 1958. For 1959 it was decided to organize a symposium on the general subject of "Classification of Sedimentary Units," the exact title to be chosen by the chairman of that symposium in consultation with the Research Committee.

5. *Report on the Earth Sciences Division of the National Research Council (Francis J. Pettijohn, S.E.P.M. Representative).*—The Division operates primarily through its various advisory and technical committees. The activities of several of these are of special interest to the members of S.E.P.M. The Division either directly (by special committees) or indirectly (by nominating panels from which National Science Foundation committees are appointed) plays an important role in furthering graduate education in geology, mineralogy and paleontology.

The technical committees of the Division are many and varied. Of these the Committee on Clay Minerals and the Committee on a Treatise on Marine Ecology and Paleoecology are perhaps of the greatest interest to members of S.E.P.M. The former, established in 1953, has organized a series of Clay Minerals Conferences, the results of which have been or are being published. The fifth Conference was held at the University of Illinois in October, 1956. The *Proceedings* of the various conferences are published and distributed by the National Research Council. Dr. Ada Swineford, of the Kansas Geological Survey and member of S.E.P.M., has been named Editor for the *Proceedings* series.

The Committee on a Treatise on Marine

Ecology and Paleoecology has completed its work. The two-volume *Treatise* is in process of publication. Both volumes will appear as a *Memoir* of the Geological Society of America.

6. *Report on the American Geological Institute* (*Francis J. Pettijohn*).—Inasmuch as *Geotimes* is now sent to most North American geologists, including all members of S.E.P.M., it seems unnecessary to report in detail the activities and projects of the American Geological Institute regularly reviewed in *Geotimes*.

Your representatives attended the meeting of the Board of Directors of A.G.I. in Minneapolis, November 2, 1956. The meeting was devoted to the usual reports of officers and committees. The principal item of interest was the report of progress made toward placing the Institute on a better financial footing and the report on the transformation of the old *Newsletter* into *Geotimes*.

Member society support has generally been revised upwards. The Geological Society of America and the American Association of Petroleum Geologists both made substantial increases in their support of the Institute. The Mineralogical Society and the Association of Geology Teachers agreed to contribute an amount equal to 10 per cent of their dues. The council of your Society, because of its status as a Technical Division of A.A.P.G., voted to contribute a per capita assessment for its Associates (most of whom are not members of the A.A.P.G.) equal to the per capita contribution made by the Members by virtue of their membership in the parent society.

According to our By-Laws, S.E.P.M. has two members on the Board of Directors of the American Geological Institute, namely its President and Past-President. The terms of the Directors are, therefore, two years beginning with the Annual Meeting of the Society in late March or early April. But the Institute Board operates on a two-year basis beginning and ending in November—the time when the Institute has its Annual Meeting. Your representatives suggest that some effort be made to bring the terms of service of its directors into better agreement with the A.G.I. operating year.

7. *Report of the S.E.P.M. Representative to the A.G.I. Government Relations Committee* (*Norman S. Hinchey*).—The A.G.I. Government Relations Committee met on April 23 and November 1, 1956. On March 31, 1957, the Committee met jointly with the A.A.P.G. National Responsibilities Committee. Among matters which were considered by the Committee at its meetings were the following topics of interest:

(1) Reports on pertinent activities of the Scientific Manpower Commission were made by Dr. Howard A. Meyerhoff. It was the feeling of the group that the profession was not always well informed on Selective Service matters which concern its members. The Committee moved to explore the possibility and desirability of a periodic summary statement of the military draft situation, such a statement to be distributed to A.G.I. members or perhaps published in *Geotimes*.

(2) Apparently, a recent report by the Bureau of Labor Statistics for the National Science Foundation does not classify exploration in geology as research. As a result the B.L.S. report states that only seven per cent of geologists are engaged in research, a smaller percentage than in any other scientific field. Complaints concerning this action were made by the A.G.I. and S.M.C. to the B.L.S, which agreed to make some changes. It was recommended by the Committee to the Board of Directors of A.G.I. that an *ad hoc* committee, under the purview of the Executive Committee of A.G.I., be established to form definitions of the terms research, development, and exploration as these terms are used in earth science and as they should be used.

(3) There was discussion of the Department of the Interior's comprehensive plan to expand and improve the national parks and monuments, a plan known as "Mission 66." It was voted to recommend to the A.G.I. Directors that a committee be appointed to learn the details of the plan and to offer A.G.I. cooperation in developing its geological aspects. An ultimate hope is that more and better geological information concerning the parks and monuments be presented to the public.

(4) The committee requested the Scientific Manpower Commision to collect and supply facts on the growth of government research and its effect upon the scientific manpower pool and its utilization.

(5) Ways and means of promoting interest in geological instruction at the U. S. Military Academies were considered, and it was suggested that the possibilities be explored with the office of the Chief of Engineers.

(6) Regretting the fact that essential geological advice is seldom used in the planning of public works, the Committee decided that the situation calls for action and appropriate steps to correct the situation will be considered at future meetings.

(7) The meeting of March 31, 1957, was a joint meeting with the A.A.P.G. National Responsibilities Committee. The current work of each of the committees was considered. The question was posed as to whether or not there might be unnecessary overlap or duplication of effort by each of the committees when they were obviously concerned with some of the same problems. After some discussion, it was agreed that it would be desirable for both of the committees to continue to operate as they are now operating. It was generally felt that any overlapping or duplication of activities would be desirable and that each of the committees might be strengthening the efforts of the other.

8. *Report of the Joint Committee on Invertebrate Paleontology* (*Raymond C. Moore*). —The project to produce a modern comprehensive textbook on invertebrate fossils by the cooperative effort of selected specialists orginated from a proposal made by B. F. Howell, of Princeton University, approximately 10 years ago. This stemmed from the evident need then existing for an up-to-date volume comparable to the Zittel-Eastman text on invertebrate paleontology published in 1900 and subsequently issued as a revised edition in 1913. The Paleontological Society is the organization that received Howell's suggestion and disposed of it by appointing him chairman of a committee to find someone bold or witless enough to accept the responsibility of trying to accomplish the objective. As a former editor of the *Journal of Paleontology*, I was approached by the committee with invitation to plan a work program and direct its operation. I responded by saying that if the Paleontological Society and Society of Economic Paleontologists and Mineralogists jointly accepted sponsorship of the project and agreed on naming me to undertake it, I would do my best to carry it forward. The societies approved a proposal to establish a Joint Committee on Invertebrate Paleontology under my chairmanship for the purpose of developing definite plans. Meanwhile, before this committee actually was appointed, the desirability of including the Palaeontographical Society as partner in the enterprise seemed clear, because participation by this society, founded more than a century ago, would bring British support and link together the leading organizations of English-speaking paleontologists. The Palaeontographical Society in 1948 agreed to be a co-sponsor of what by then was designated as a "Treatise on Invertebrate Paleontology." Accordingly, the joint committee was set up, with ten members from the Paleontological Society, ten members from the Society of Economic Paleontologists and Mineralogists, and ten members from the Palaeontographical Society.

The first task was to plan the scope of intended text and illustrations, and to prepare a schedule of author assignments. Next there were decisions to make about innumerable features of style. How could reasonable unity be attained in materials prepared by dozens of different workers working in widely scattered parts of the world? Most of all, where was money to pay costs of making needed illustrations and other items of expense? The sponsoring paleontological societies had not agreed to supply any funds and obviously their resources would be quite inadequate for payment of any considerable costs. At this stage the Geological Society of America was approached and must be credited for financial underwriting of the *Treatise* effort. Without this support we could have accomplished little. Counting direct and indirect appropriations made by the Geological Society for preparation of *Treatise* materials (not including publication costs), more than $40,000 has been furnished from 1948 to 1957. Also, as regards publication, account should be taken of the fact that all composition of type and printing work done by the University of Kansas Press for volumes of the *Treatise* has been undertaken without charge of a single dollar of profit to the Press. Thus, the sale price of published volumes is very much less than

otherwise would be possible.

To date, 7 of the 22 scheduled parts of the *Treatise* (excluding general Introduction and consolidated Index) have been published. These represent a total of 1,958 pages of text and illustrations, the latter containing more than 11,000 individual figures. The most recently issued part is the volume on Ammonoidea, distribution of which began in March, 1957; this constitutes a truly unique book in that in addition to authoritative description and illustration of morphological features of these fossils, it contains diagnoses and figures of virtually all known genera in the world recognized as valid, accompanied by notation of type species and all synonyms. The authors are four American and four British paleontologists who include outstanding leaders in study of the groups treated. Volumes such as this one serve to establish the *Treatise* as the most complete and authoritative text in the world concerning invertebrate fossils. This Society and the others that are sponsors of the *Treatise* have reason to take great pride in the publication of the volume on Ammonoidea.

Work is proceeding at varied pace on the yet unpublished parts of the *Treatise*, those farthest advanced being Part O on trilobitomorphs, Part Q on ostracodes, Part I on chitons, scaphopods and some gastropods, Part W on conodonts, worms and problematica, and Part C on foraminifers. These will go to press as rapidly as they can be made ready. A lull in appearance of Treatise volumes now must be anticipated because of the processing time required after materials are ready for the press. Experience shows that this amounts to about six months for small units and as much as eleven months for large ones.

9. *Report of Representative to Second Nuclear Engineering and Science Conference (Roland F. Beers)*.—The second Nuclear Engineering and Science Conference was held in Philadelphia on March 11 to 14, 1957. Together with three related programs running the same week, the Conference is also known as the 1957 Nuclear Congress. The Congress was sponsored by 24 national and international organizations, including the American Geological Institute, to which the Society of Economic Paleontologists and Mineralogists appointed your reporter as a delegate. Professor Paul F. Kerr served as Chairman of the A.G.I. program, and W. R. Thurston as Executive Secretary. The papers presented by the A.G.I. members were coordinated by Professor Kerr's committee through the office of Mr. Thurston at the National Academy of Science-National Research Council, following preparation of a list of invited papers by the A.G.I. committee. The entire Congress program was coordinated by the Engineers Joint Council of New York.

The technical program consisted of 33 separate sessions from Monday through Thursday, and in addition, 4 other technical sessions or addresses at luncheon or dinner meetings. Topics covered in these sessions are as follows: Plant Containment Concepts and Design, Fuel Cycles—Fuel Production and Recovery, Protection of Water Supplies, Educational Use of Reactors, Waste Disposal, Merchant Ship Safety; Reactor Operation and Maintenance, Standardization in the Nuclear Field, Primary Coolant Systems, Plant Components, New Limits and Codes for Radiation Protection, Shielding-Structural Protection and Control of Fission Products, Radiation Processing, Reactor Design, Uranium Metallurgy and Radiation Effects, Reactor Plant Instrumentation, Reactor Control and Simulators, Natural Resources, Metallurgy of Reactor Materials, Heat Transfer and Heat Evolution, Problems Related to Heat Transfer, Metallurgy of Uranium-Zirconium and Uranium-Niobium Alloys, and Reactor Instrumentation Development.

Separate sessions were held on Thursday and Friday covering "Hot" Laboratories and the 5th Atomic Energy in Industry Conference. Preprints of many of the technical papers were available at the office of the American Society of Mechanical Engineers at 30¢ each prior to the meetings. The program contains a list of the titles and authors of available papers and orders may be placed with A.S.M.E.

10. *Report of Pacific Coast Section (J. D. Bainton)*.—The Pacific Section has an active paid up membership of 161 and a balance in the treasury of $1,873.90.

This year, S.E.P.M. membership awards were granted by the Pacific Section to 16

students from various Pacific Coast Colleges and Universities. The faculty of the Geology or Paleontology Department of each school nominated the student to receive this award, which included subscriptions to both Journals. This project was voted on and established by the members at the annual meeting in Los Angeles in November, 1956.

The monthly Biostratigraphy Seminar, which is sponsored jointly by the Pacific Section S.E.P.M. and the Bakersfield Evening School, is again in progress. Eight papers by research workers from West Coast schools, covering the fields of stratigraphy, paleontology, and ecology, are on this year's program. Edwin H. Stinemeyer is chairman, and the average attendance at the meetings is approximately 40.

The S.E.P.M. Pacific Section will sponsor their annual dinner meeting and field trip this year on May 17th and 18th. Dr. Francis P. Shepard is chairman of the event and E. Dean Milow and R. R. Lankford are co-chairmen. The paleontology, stratigraphy, and sedimentation of the cliff exposures, in the vicinity of Scripps Institution of Oceanography and the Torrey Pines area, will be studied and sampled. Mr. Milow will present a paper on the Stratigraphy and Paleoecology—La Jolla Area at the Friday evening dinner preceding the trip.

The Pacific Section S.E.P.M. will again cooperate with the A.A.P.G. and S.E.G. in putting on the Annual Fall Meetings at Los Angeles on November 7th and 8th. A half-day technical session and dinner meeting are being planned by Dr. E. L. Winterer, program chairman.

A dinner dance was held in December which was co-sponsored by the S.E.P.M.-A.A.P.G.-S.E.G.

11. *Report of Gulf Coast Section (Lloyd M. Pyeatt).*—The 1956 annual meeting of the Section was held in San Antonio, Texas, October 31-November 2. The first day of the two days of Technical Sessions was a joint meeting with the Gulf Coast Association of Geological Societies. The second day the Gulf Coast Section held its own sessions concurrently with the other meeting. Papers were presented by Section members at each of the sessions.

The Annual Business Meeting was held on November 2nd in San Antonio at the close of the Technical Sessions, with President E. H. Rainwater presiding. Following the reports from the Secretary, Treasurer, and Committee Chairmen, there was a discussion of projects which the Section is undertaking. The meeting was then turned over to the new president, Lloyd M. Pyeatt.

Two field trips in the Gulf Coast during 1956 were sponsored by the Gulf Coast Section. On May 3, 4, and 5 a large group of geologists was shown the famous Miocene localities of western Florida by Messrs. Harbans S. Puri and Robert O. Vernon. A guidebook entitled, "A Summary of the Geology of Florida with Emphasis on the Miocene Deposits, and a Guide to the Miocene Exposures," was prepared by the Florida Geological Survey, Dr. Herman Gunter, Director. This publication may be purchased from the Florida Geological Survey, Tallahassee.

On November 3, the day following the annual meeting of the Section, a field trip was conducted especially for the Gulf Coast Section by Robert Pavlovic, Fred L. Stricklin, Jr., Keith P. Young, and Kenneth J. DeCook. Dr. John R. Sandidge was chairman of the committee which planned and conducted the trip into the classic Lower Cretaceous area between San Antonio and Austin, Texas, and prepared a guidebook entitled, "Guidebook, Lower Cretaceous Field Trip, November 3, 1956," which can be obtained from the South Texas Geological Society, San Antonio.

12. *Report of Permian Basin Section (Hugh N. Frenzel).*—The Permian Basin Section has completed its third year of activities and the first full year of operation under its constitution. During this first year the constitution was amended to require that officers of the Permian Basin Section be members of the national S.E.P.M.

P.B.S. membership stands at 270 which is comparable with previous years despite the fact that 40–50 new members have been added each year. Society funds total $1,041.75. It is believed that sale of publications will tend to increase this fund. The Executive Committee decided to use surplus funds to conduct "Little Distinguished Lecture Tours" of outstanding speakers to several of the Permian basin towns.

Activities during the year included the first annual meeting held in Fort Worth, Texas, May 11, 1956. Meeting attendance was about 80. A technical session was held with seven papers being given. On May 12th a field trip was held to study the "Nill Creek Beds of the Lower Strawn of Parker County." P.B.S. members in Fort Worth under the leadership of Wendell J. Stewart, Gregory Turner, Donald Zimmerman and Leo Hendricks organized the meeting and field trip. The 1956 officers taking over at the close of the meeting were: Hugh N. Frenzel, President; W. Frank Dameron, 1st Vice-President; Frank B. Conselman, 2nd Vice-President; Tom Schneider, Secretary; and Ed A. Vogler, Treasurer.

The second annual meeting was held in Lubbock, Texas, March 15 and 16, 1957. Meeting attendance was 160. Twelve papers were given during the technical sessions. The P.B.S. student chapter at Texas Technological College was host society and the meeting was organized under the leadership of John P. Brand, Granville Waters, F. A. Wade, and Frank B. Conselman. The 1957 officers taking over at the close of the meeting were: W. A. Waldschmidt, President; W. W. Roye, 1st Vice-President; Donald A. Zimmerman, 2nd Vice-President; M. R. Stipp, Secretary; and Booker L. McDearmon, Treasurer.

A two day field trip will be held April 26 and 27, 1957, to study the Wolfcamp rocks of the Glass Mountains.

13. *S.E.P.M. President's Report* (*Robert R. Shrock*).—Finances remain our Society's most serious problem. The General Fund showed a *loss* of $637.17 in 1956 as compared with a profit of $5,362.37 for 1955. This loss is partially due to increased printing costs. The Publication Fund showed a *profit* of $1,860.88 in comparison with a profit of $2,502.74 for 1955. Thus the over-all profit for the year 1956 amounted to $1,223.71, but part of this amount represents inventory. It should be pointed out that in 1957 printing costs will be substantially increased, and it is largely because of this increase that the council has voted to amend the by-laws so as to provide for the increase in dues subsequently approved in the Business Meeting.

Successive increases in printing costs are becoming more and more of a problem for a Society like ours, with a relatively small membership (1300+) and two journals, one of which, the *Journal of Paleontology*, is abnormally expensive because of the large number of costly illustrations. The Paleontological Society, with which we have an arrangement for publishing the *Journal of Paleontology*, is struggling with this same problem, and their President, G. A. Cooper, has appointed a special committee "to study the future of the *Journal*."

Our journals represent the most important activity of our Society, and its chief reason for existence, and ways will have to be found to meet the rising costs of printing, or the size and number of issues will have to be drastically reduced—an action which would be disastrous to the future growth of our Society. The modest increase in dues, and in the subscription rate to non-members for the *Journal of Sedimentary Petrology*, approved for next year will help to some extent in meeting future increases in printing costs, but other income will have to be found if our journals are to flourish and meet the future demands on them.

Quite a different problem, and one which is highly encouraging, is the underwriting of special publications, symposia, and the like that have a good chance of being self-liquidating. These special publications are not only highly desirable for members of our Society; they help to replenish the Publication Fund and hence make possible publication of new items.

A special committee, composed of Stuart A. Levinson (Chairman), A. R. Loeblich, Jr., and W. C. Bell, was appointed last year and charged with studying the whole problem of publication policy. Their excellent report was submitted to the council at the annual meeting in St. Louis and becomes the starting point for positive future action.

This year will see the appearance of Special Publication No. 5 on *Regional Aspects of Carbonate Deposition*, the results of a symposium held here in St. Louis in 1954. As of March 1, 1957, 1,585 of the first edition of 2,500 (increased from 2,000 because of the heavy prepublication ordering) had been sold by prepublication orders, and there is every indication that this symposial report will be out of print in a very short time.

Our membership grew vigorously through

the year, as shown in the following tabulation:

	March, 1956	*March, 1957*	*Increase*
Members.....	900	994	94, 10.4%
Associates.....	280	305	25, 8.9%
Correspondents.	5	6	1, 20 %
Honorary Members.....	3	3	0, —
	1,188	1,308	120, 10+%

Nevertheless, our total membership is far below what it should be to support our program of activities. Our Technical Program is becoming an increasingly more important part of the annual joint meeting with the A.A.P.G. At New York, in 1955, 40 papers were presented on the S.E.P.M. program as compared with 62 on the A.A.P.G. program. In Chicago, last year, 42 papers (including those in two symposia) were presented in the S.E.P.M. program as compared with 31 on the A.A.P.G. program! At the 1957 meeting in St. Louis, our Society will present 47% of the papers on the Technical Program (25 papers by S.E.P.M. compared with 28 papers by A.A.P.G.). Clearly this growing importance of our Society must be further increased by the concerted effort of all members to get new members, particularly from the growing number of students and recent graduates, and from younger men offering papers on our technical program.

We regret that W. M. Furnish finds it necessary to resign editorship of the *Journal of Paleontology* at the end of his present term, as his efficient service has been much appreciated. Fortunately, we shall have the editorial services of M. L. Thompson for the coming year, and I wish to express for the Society our gratitude to Dr. Thompson for accepting the heavy and important responsibility of Editor. Our editors are our most important officers in that they are directly responsible for the nature and quality of our two journals. Accordingly, we also record our gratitude to J. L. Hough for his usual efficient handling of the *Journal of Sedimentary Petrology*, and we are pleased to know that he will continue as editor next year.

In order to conform with action taken by the Executive Committee of the A.A.P.G., the S.E.P.M. will henceforth make an annual contribution to the A.G.I. that will be determined by the number of associate members as of December 31 of each year. The amount that will be contributed in 1957 will be approximately $216.

Selection of candidates for our presidents and vice-presidents has been of growing concern to some of us who have been more closely associated with administrative affairs of the Society than is the general membership. Last year a special committee was appointed to study this problem and to suggest constructive action. This committee, consisting of Stuart A. Levinson (chairman), W. C. Krumbein, and Grover Murray, made its report to council at the April, 1956, meeting in Chicago, and recommended the following: (1) that the two nominating committees be appointed from the membership-at-large; and not an Eastern and Western Committee, and that on each nominating committee there be wide geographic distribution of members; and (2) that the activities of the Research Committee be directed by a chairman and a vice-chairman, to be appointed by the president, with approval of the council, from the active members of the committee and that the term of office of the chairman shall be one year. Approval was given to these recommendations, and they were put into effect immediately.

The Research Committee performs some of the most important functions of our Society; hence its guidance and membership should be a prime concern not only of the council but also of the membership-at-large. The importance of recent symposia organized by this committee has raised the question of how best such symposia can be planned well in advance and their papers published with maximum speed. A special committee recommended to council, and council approved, that Research Committee symposia be determined two years in advance and that the ultimate chairman of the symposium be appointed vice-chairman two years in advance so as to have adequate time to organize the symposium. It is hoped that this procedure will make it possible to have all manuscripts in hand at the time of the meeting, or within a few months thereafter, so that publication, if approved by the Standing Committee on Publications and by council, can follow promptly.

The S.E.P.M. became affiliated with the

American Association for the Advancement of Science following council approval of the recommendation of a special committee set up last year by President Pettijohn, to investigate and report on the matter. This committee, consisting of Chalmer L. Cooper (chairman), J. Marvin Weller, and H. N. Frenzel, reporting to council at the April, 1956, meeting in Chicago, recommended affiliation, and the council approved. Subsequently, appropriate action was taken, and the Society was notified that its request for affiliation had been approved on December 27, 1956. Messrs. Verner Jones and George Wilson were appointed to serve as S.E.P.M. representatives to the A.A.A.S. Council.

During the last year, our representative on the Advisory Committee on Radioactive Mineral Exploration, Harold N. Fisk, informed me that it had been unanimously recommended that the committee be dissolved as it felt that the original objectives of the committee had been accomplished. These objectives were to encourage and urge companies exploring for oil and/or gas to combine with such exploration the search for radioactive minerals, and to advise those interested as to prospective areas, methods of exploration, and sources of information. Fisk reported that in the four years since the committee was first organized, many oil companies have made the search for uranium part of their program in exploration and the committee felt that its efforts had been adequately rewarded.

A special committee was appointed to study and report on the question: How many copies of our two journals should be published in the future? This committee, consisting of H. B. Stenzel (chairman), J. L. Hough, W. M. Furnish, W. C. Krumbein, and William Evitt (for the Paleontological Society), was to report to council at the 1957 annual meeting, but, unfortunately, no report was submitted because of the chairman's illness. In connection with the work of this committee, H. B. Stenzel was appointed by council to be the S.E.P.M. representative on the Joint Committee with the A.A.P.G. to study reprinting back issues of S.E.P.M. publications.

Services were given during the year by the following, to whom I extend my sincerest gratitude: (1) two nominating committees consisting respectively of H. N. Fisk (chairman), L. M. Cline, and S. G. Wissler, and H. S. Ladd (chairman), B. Kummel, and F. B. Phleger; (2) Daniel A. Busch as Vice-Chairman, Presiding Officer for S.E.P.M., and member of the Steering Committee for the 1957 joint annual meetings in St. Louis; (3) Curt Teichert and Alfred R. Loeblich as chairman and vice-chairman, respectively of the Research Committee and also as organizers of the Symposium on Biostratigraphy, and V. E. Barnes, R. V. Hollingsworth, D. L. Inman, Stuart A. Levinson, and Haydn Murray as members; (4) W. J. Plumley as chairman of the Symposium on Geochemistry at the St. Louis meeting; (5) Hans Thalmann as official representative and Grover E. Murray as a professional delegate to the XXth International Geological Congress at Mexico City last summer; (6) R. C. Moore as S.E.P.M. representative on the committee for preparation of the *Treatise on Invertebrate Paleontology;* (7) Jules Braunstein as S.E.P.M. representative on the A.G.I. Glossary Committee, whose *A Glossary of Geology* is now in press and will be issued as a publication of the American Geological Institute; (8) the various chairmen and co-chairmen of the technical sessions of the annual meeting, particularly Vice-President R. V. Hollingsworth, who had the primary responsibility for the St. Louis Technical Program; (9) Samuel P. Ellison as chairman of the Resolutions Committee for the annual meeting; and finally (10) Robert H. Dott, and his efficient secretary, Mrs. Ruth Tener, for valuable advice and assistance on many matters.

It was moved, seconded, and carried that the above reports be approved and that they be published in the Society's publications.

The following change in the S.E.P.M. By-Laws was presented to the business meeting (brackets indicating deletions, italics indicating additions):

ARTICLE I. DUES

2. The annual dues of members and associates of the Society who desire only the *Journal of Paleontology* shall be [eight dollars ($8.00)] *ten dollars* (*$10.00*). The annual dues of members and associates who desire only the *Journal of Sedimentary Petrology* shall be [five dollars ($5.00)] *seven dollars* (*$7.00*). Members and associates may receive both Journals by the payment of [thirteen dollars

($13.00)] *seventeen dollars* (*$17.00*). Members of the Society who are also members of the Paleontological Society and receive the *Journal of Paleontology* through the latter Society, may retain membership in the Society of Economic Paleontologists and Mineralogists by the payment of [one dollar ($1.00)] *two dollars* (*$2.00*) per year dues. . . .

The foregoing change was approved by a unanimous vote, the change in the *Journal of Paleontology* dues and the Joint Society dues being contingent upon similar action by the Paleontological Society.

The meeting was turned over to incoming President R. V. Hollingsworth.

The Resolutions Committee, composed of Samuel P. Ellison, Jr. (chairman), J. L. Hough, and Stuart A. Levinson, presented the following "Resolutions of Thanks."

BE IT RESOLVED THAT in behalf of the Society we extend an expression of our sincere thanks to the following:

TO R. V. HOLLINGSWORTH, chairman, and the members of the S.E.P.M. Technical Program Committee and to the speakers for the high quality of papers on the 1957 program;

TO DANIEL A. BUSCH, general chairman of the S.E.P.M. convention, for his capable handling of the details of the meeting;

TO CURT TEICHERT, chairman of the Research Committee, and A. R. LOEBLICH, JR., vice-chairman, for the excellent research symposium on Biostratigraphy;

TO SHEPARD W. LOWMAN, for arranging the papers on Paleontology and Stratigraphy;

TO SHERMAN A. WENGERD, for preparation of that part of the program dealing with Sedimentary Mineralogy, Petrology, and Sedimentology;

TO WILLIAM J. PLUMLEY and HEINZ A. LOWENSTAM, for arranging the papers on Geochemistry of Sedimentary Materials;

TO RUFUS LEBLANC, for editing our special publication, *Regional Aspects of Carbonate Deposition;*

TO HAROLD T. MORLEY, general chairman of the convention, and to the chairmen and members of all the convention sub-committees, for their efforts in the organization of the St. Louis meeting;

TO THE EXECUTIVE COMMITTEE of the A.A.P.G. for appropriating $1,500.00 as office rent for the Society Headquarters at Tulsa and for allowing the Society to share in the net income from the 1956 Chicago Convention:

TO ROBERT H. DOTT, for his valuable service to the Society as its Business Manager;

TO OUR EDITORS, W. M. FURNISH and JACK L. HOUGH, for their untiring efforts in behalf of the *Journal of Paleontology* and the *Journal of Sedimentary Petrology;*

TO THE JEFFERSON HOTEL, for providing excellent convention headquarters facilities;

AND TO THE CITY OF ST. LOUIS, for the use of the Kiel Auditorium and for full cooperation at all times.

It was moved, seconded, and carried that the above Resolutions be adopted.

Before adjournment at 6:00 P.M. Past-President Shrock read a SPECIAL RESOLUTION on the death of WILLIAM HENRY TWENHOFEL: this is printed as a memorial on a foregoing page of this number of the *Journal.*

SPECIAL NOTICE

The 1957 S.E.P.M. and A.A.P.G. program, containing abstracts of papers presented at the St. Louis Meeting, will be mailed free, on request, to anyone desiring a copy. Orders should be sent to: S.E.P.M. Headquarters, Box 979, Tulsa 1, Oklahoma.

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REVIEWS

STROMATOPOROIDEA SOVETSKOGO SOYUZA, by V. I. Yavorsky. Trudy Vsesoyuznogo Nauchno-issledovatelskogo Geol. Inst., Minister. Geol. i Ochrany Nedr, new ser., vol. 8, p. 1–173, pl. 1–89, text-fig. 1–11, 1955.

This is the mature work of the veteran student of Stromatoporoidea, who published his first work on the subject in 1929. Yavorsky's Stromatoporoidea of the Soviet Union is one of the four or five most important papers ever published on the Stromatoporoidea, and for one working on Stromatoporoidea, it must be consulted daily, along with Nicholson's Monograph of British Stromatoporoids (1886–1892), Parks' Devonian Stromatoporoids of North America, 1936, and Lecompte's Les Stromatoporoides du Devonien Moyen et Superieur du Bassin de Dinant (1951–1952), for the same species may occur in different continents at the same horizon.

Yavorsky's paper is not a monograph of the Russian stromatoporoids, but a description of species in new, extensive collections. He described and figured 195 species, ranging from the Ordovician to the Upper Jurassic, of which 147 are new. Yavorsky gave a summary of the historical development of the study of the Stromatoporoidea and discussed the structure and classification of many earlier authors. He accepted and modified the classification developed by Nicholson, 1886, in which there are two groups of families, the Hydractinoid group without zooidal tubes, with the families Actinostromidae and Labechiidae, and the Milleporoid group with zooidal tubes, with the families Stromatoporoidae, Idiostromatidae, and Milleporellidae. He included five post-Devonian genera, which the reviewer does not consider Stromatoporoidea but Sphaeractinoidea. The 89 plates of figures are photographs, apparently unretouched, and tend to have 8 figures on a plate, each 50×60 mm., mostly with the optimum magnification, ×10. The collotype figures are among the best which have ever been published of the stromatoporoids.

Yavorsky recognized two new genera: *Ferestromatopora*, embracing three species, which differ from *Stromatopora* in lacking "zooidal" tubes (pseudozooidal tubes, superposed galleries) and lacking pillars longer than one interlaminar space; *Paramphipora*, embracing 12 species which differs from *Amphipora* in lacking a median dark line in the pillars, of which 8 are Silurian species. A brief bibliography is given.

The descriptions and figures are adequate for recognition although consideration is omitted of some important characters, such as the tissue, whether compact, fibrous, porous, flocculent or maculate. A magnification of ×20 and ×40 are necessary and show tissue structure. The lack of keys and tables which point out the distinctions between species makes identification difficult. Yavorsky is not meticulous in observing some of the Rules of Nomenclature. He did not designate any genotype for either of his two new genera, as demanded by Art. 25, and he prefers the name *Beatricea* Billings, 1857, over *Aulacera* Phillips, 1843. Yavorsky does not mention Parks' new genera, *Anostylostroma*, *Stictostroma* and *Trupetostroma*, although he has species which fit those genera. He has six species of *Gerronostroma* Yavorsky, 1931, a genus not yet well characterized. He has one additional species of his *Clathrocoilona*, 1931, which scarcely can be distinguished from *Gerronostroma* and *Trupetostroma*. It may be objected that his *Cryptophragmus gracilis* (a homonym) does not have the essential character of *Cryptophragmus*, the cystose column, but is something added to a hollow column, and consists of finely tabulate tubes having more the appearance of an alga than that of a stromatoporoid. Yavorsky does not mention Lecompte's Memoir, 1951–52, nor his new genera *Atelodictyon* and *Synthetastroma*. He does not distinguish *Parallelopora* from *Stromatopora*, for his *Stromatopora pellucida* is a typical *Parallelopora*, with long pillars and coarse maculae in vertical ranges.

Yavorsky's paper makes a great addition to our knowledge of the obscure but abundant stromatoporoids. He is to be commended for this and the many other contributions he has made to our knowledge of the stromatoporoids. The book is entirely in

Russian so that easy use cannot be made of Yavorsky's work by most students interested in the subject, and translation is too expensive. It would have been better if there had been an English summary, as is true of some of his earlier works.

J. J. GALLOWAY
Indiana University
Bloomington, Indiana

TRIASSIC DICYNODONT REPTILES. Part I: THE NORTH AMERICAN GENUS PLACERIAS, by C. L. Camp & S. P. Wells. Part II: TRIASSIC DICYNODONTS COMPARED, by C. L. Camp, Memoirs of the University of California, vol. 13, p. 255–348, pl. 30–33, fig. 62, 1956.

Terrestrial deposits of Permian and Triassic age in North America are singularly lacking in remains of therapsid reptiles. Of the limited number of published reports, only a few can be considered valid. The report of C. Camp and S. Wells upon the dicynodont *Placerias* from lower part of Chinle formation of Arizona assumes great importance as a description of the only genus known from adequate materials, and as a considered analysis of the meanings of these materials with respect to distributions and migrations of terrestrial vertebrates during the Permo-Triassic times.

The report is divided into two sections. The first, by C. L. Camp and S. P. Wells, presents a survey of the history of discoveries of therapsid reptiles in North America, and a detailed analysis of the morphology of *Placerias*. The second, by C. L. Camp, considers the relationships of *Placerias*, geographic inferences based upon these relationships, and the phylogeny of the dicynodonts.

Only a very few therapsids have been reported from Permian and Triassic beds of the United States. None of those from the Permian has as yet been certainly confirmed. Except for the remains from the *Placerias* quarry, near St. Johns, Arizona, the authentic Triassic therapsids are represented by extremely fragmentary and poorly preserved specimens. This quarry has yielded only disarticulated skeletal elements, but remains of at least 39 individuals have been identified. All the specimens are referred to a new species, *Placerias gigas* Camp and Wells. Both cranial and postcranial elements of this species are described in great detail and fully illustrated by excellent drawings.

In the second section, Triassic dicynodonts from South America, South Africa, and China are compared with *Placerias*. Skulls of representatives of the most important genera are figured. A series of indices based on pairs of skull measurements of *Placerias* are tabulated, and then used for comparisons with indices of the other genera: *Stahleckeria*, "*Gordonia*," *Kannemeyeria*, *Aulacocephalodon*, "*Dicynodon*" *trautscholdi*, *Daptocephalus*, *Cistacephalus*, *Eurychororinus*, and *Brachyprosopus*. From these comparisons and careful qualitative analyses, it is concluded that *Kannemeyeria*, *Stahleckeria* and *Placerias* form a natural group. *Placerias* and *Kannemeyeria* appear to be closer to each other than is either to *Stahleckeria*, and *Kannemeyeria* is considered to be most primitive of the three.

Morphological and distributional data suggest a northern origin and spread of the kannemeyerid dicynodonts. Direct migration of the South American stahleckerians from South Africa cannot be assumed with any confidence. Although it is unnecessary to invoke southern continental connections to explain the Triassic distribution of the dicynodonts, the data now available do not entirely disprove the concept that such connections existed during the Triassic. Other vertebrate evidence, related to the origin of the South American Triassic vertebrate faunas, does not conclusively support the idea of southern intercontinental connections, although it does not oppose it as directly as does that of the dicynodonts.

A phylogeny of the dicynodonts is presented in a chart which brings together data on stratigraphic and geographic distribution of the major groups. The relationships of the various types are shown and reasons for the inferences are discussed in the accompanying text.

This report cannot fail to be extremely useful and stimulating, both in its detailed descriptions, and in its broader aspects. A number of points that are made stand in notable contrast to widely prevalent views upon the existence of intercontinental connections in the southern hemisphere in the Permian and Triassic. Upon such a concept is based the idea of the faunas and floras of

Gondawanaland. It demonstrates graphically how gaps in the record, such as those of the late Permian and parts of the Triassic of North America may lead to misinterpretations, and how a single find, such as that of the *Placerias* quarry, can act to aid in correction of errors based upon negative evidence.

EVERETT C. OLSON
Walker Museum of Paleontology
University of Chicago
Chicago 37, Illinois

STROMATOPOROIDEA, by Marius Lecompte, in TREATISE OF INVERTEBRATE PALEONTOLOGY, Part F, COELENTERATA, Geol. Soc. America and Univ. Kansas Press, 1956, p. F107–F144, text-fig. 86–114. $7.00.

Dr. Lecompte, of the Institut Royal des Sciences Naturelles de Belgique, undoubtedly became interested in the Stromatoporoidea through his early work in the 1930s, on the Devonian reefs of Belgium. As a result of undertaking the description of a large fauna as well as locating and checking important types in museums, "Les Stromatoporoides du Bassin de Dinant" (Inst. Roy. Sci. Nat. Belgique, Mém. 116, 117, p. 1–369, pl. 1–70) was published in 1951 and 1952. This important work and the 1952 publication of, "Revision des stromatoporoides Mesozoiques des collections Dehorne et Steiner" (Inst. Roy. Sci. Nat. Belgique, Bull., vol. 28, no. 53, p. 1–39, pl. 1–3) serve as bases for the present article in the Treatise of Invertebrate Paleontology.

As the title indicates, the paper deals with the order Stromatoporoidea, but the order is extended to include related hydroids which some students would place in the orders Sphaeractinoidea and Hydroidea. Thirty-five Lower and Middle Paleozoic genera, typical Stromatoporoidea, as well as twenty-five Upper Paleozoic and Mesozoic genera, better placed in the Sphaeractinoidea, are included. The reviewer considers the Stromatoporoidea s.s. to range from the Middle Ordovician to the Upper Devonian, not the Cambrian to Cretaceous as stated. The topics considered in the paper are morphology, systematic position of stromatoporoids, evolution, classification, paleoecology, and systematic descriptions which consist of brief synopses of families and genera with figures of the more important genera. The work is well organized; the illustrations consist of reproductions of photographs of thin sections, and photographs of previously published illustrations. The figures vary widely from excellent (fig. 102, 1) to unrecognizable (fig. 105, 4). The ones grossly inked over showing laminae and pillars without finer detail, would suggest a tendency to ignore the importance of the tissue (fig. 91, 1; 94, 1; 107, 1–4, for example).

There are several typographical errors in the work, as well as inconsistencies and factual errors. An example occurs on page F131. The genotype of *Stylodictyon* is *Syringostroma columnaris* Nicholson, not "*Syringopora columnaris* Nicholson." On page F117, fig. 115 should be fig. 100, and fig. 100, 101, should be fig. 101, 1, 2. Fig. 98, 1b; 106, 3; 109, 3b; and 110, are upside down. Fig. 105, 1a is oblique and upside down. Fig. 99 is on its side, with the base to the left. It seems probable that the author did not see the proofs. Fig. 114, 3, "*Aulocerium*," is a typical fistuliporoid bryozoan, as examination of the sections will demonstrate.

In the morphological considerations, the stromatoporoid skeleton is regarded as trabecular (made of rods). The Stromatoporoidea s.s. have coenostea composed of concentric or horizontal, platelike laminae and vertical or radial pillars. However, the Sphaeractinoidea of the Mesozoic have both vertical and horizontal skeletal elements composed of trabeculae—a fundamental factor which is not taken into consideration in Lecompte's classification. The radial processes of the *Actinostroma* are the only examples of a trabecular structure in the laminae of Stromatoporoidea. The implication that "lamellae" are fundamentally meshes is therefore not correct for the Stromatoporoidea. The upward branching Y-shaped pillars in "*Clathrodictyon*" (fig. 94, 2) cause the vermicular appearance noted in tangential section, not some trabecular structure in the laminae. The term "lamellae" seems unnecessary since the term laminae has been used in the same sense by nearly all students of stromatoporoids who have published in English. The author is correct in questioning the commonly accepted zooidal

nature of "zooidal tubes" (p. F112, F122) extending through laminae.

The axial canals of dendroid forms are considered by Lecompte to be axial canals of astrorhizae, (p. F115, F126).

Lecompte accounts for the light-colored microlaminae of some stromatoporoids by an unexplained bleaching process (p. F112). The light or dark color of the microlaminae must be inherent to the skeleton, for it is persistently light in the genera *Clathrocoilona*, *Stictostroma*, and *Trupetostroma*, and persistently dark in most genera of the family Stromatoporidae, as *Parallelopora* and *Syringostroma*. The tendency of skeletal structures to become thickened in Stromatoporella is emphasized but such a condition is much more prominent in the genera *Stromatopora* and *Syringostroma*.

Lecompte did not adhere to the characteristics of the genotype of *Stromatoporella* in his publication on the Belgium stromatoporoids and does not mention the characteristic ring-pillars in the generic diagnosis (p. F131); however, on page F113 of the present paper he mentions the "annular appearance of pillars," the characteristic structure of the genus.

Under microstructure (p. F118), the statement that fibrous skeletal structure is seen only in *Amphipora* among the Paleozoic stromatoporoids is not correct. Transversely fibrous wall structure can be demonstrated in several genera, *Anostylostroma* Parks, *Stictostroma* Parks, (1936, Univ. Toronto Studies, Geol. Ser. No. 39, p. 48), *Stromatoporella* and *Gerronostroma*. Recrystallization could scarcely account for the transversely fibrous appearance of the tissue as is suggested. Well-preserved specimens show distinctly the transverse fibers. The greater the amount of recrystallization, the greater the destruction of the original microstructures, such as fibers and pores.

In the discussion of the "cellular type" (p. F118) of skeletal elements (a misnomer for maculae), the value of microstructure is not emphasized but minimized and denied. The required vertical and tangential sections of each specimen are not used to illustrate skeletal structure. For example, the structure of *Stromatoporella* may appear much the same as *Stromatopora* in tangential section as is shown (fig. 102, 3, 4), but the tissue is clearly different in the vertical section. In vertical section, microtissue of *Stromatopora* appears the same as in tangential section, whereas in *Stromatoporella* the tissue is seen to contain transverse or irregular anastomosing alveoli. Lecompte does not present some of the pertinent information to support his conclusions. The statement (p. F118) that, "A tubular structure which has been recorded by Nicholson and others in various species (as *Stromatoporella granulata*, *S. eifeliensis*, *Parallelopora ostiolata*, *P. goldfussi*, *Stachyoides verticillata*) is non-existent, for identification of it rests on misinterpretation of sections in one plane," is not borne out by the observable structures in most specimens. The reviewer has many examples of *Stromatoporella* in which the tubules in the tissue show distinctly in two planes. Indeed, Lecompte's fig. 102, 4, from Nicholson, is a good example of tubules cut transversely in the tangential section. It is also not difficult to show the rods in *Parallelopora* which he questions, for he figures them (fig. 102, 1 and 109, 2b). The description of the tissue of *Synthetostroma* is not clear. Fig. 96 and 102, 2 do not show sufficient detail to demonstrate the microstructures they are supposed to illustrate. The Mesozoic forms are not, as is stated, similar to Paleozoic forms in all other respects except microstructure. The greatest distinction is the trabecular nature of horizontal coenosteal elements which are laminae in the Stromatoporoidea. Furthermore, the difference in microstructure is a valid basis for separating the two groups. The absence of stromatoporoids or related forms from Mississippian and Pennsylvanian horizons is another argument for separating the two groups in time.

Lecompte's comments on the systematic position of the stromatoporoids and the section on relation of the Stromatoporoidea to Foraminifera are well presented.

In the last sentence under the discussion of evolution (p. F123), Lecompte mentions a transformation of the astrorhizal system, but gives no indication of what the transformation is.

Lecompte follows Ripper's conclusion (1937, p. 194) that most dendroid stromatoporoids belong to genera, or at least to families, composed mainly of massive forms.

In each example of "dendroid and massive pairs having almost identical skeletal structure" (p. F126), there are distinctions in addition to being dendroid or massive, which are not mentioned, such as tissue or pillar and laminar architecture. Therefore, the close relationship implied is discounted.

In the classification, Lecompte puts first one of the latest occurring genera of Stromatoporoidea s.s., and in general does not consider the geologic occurrence. As a result, his treatment of the family Labechiidae is the most inadequate. The intermixture of Paleozoic and Mesozoic genera in the same families, of ramose and massive forms, and of forms with all varieties of microstructure, results in a bewildering assemblage of genera in every family.

In the synopsis of the Actinostromatidae (p. F127), the coenosteum is referred to as hexactinellid. The term defeats a previous argument presented in the topic on systematic position (p. F121), that the stromatoporoids are not sponges. The radial processes which make up the laminae of *Actinostroma* are not hexactinal as are the spicules in a hexactinellid sponge, nor do the pillars with the radial processes make up discrete units fused together as in the dictyonine group of hexactinellid sponges. The laminae and pillars of which the coenosteum is composed are added during astogeny, just as a septum in a colonial coral or a zooecial wall in a bryozoa is added in keeping with the orderly plan of colonial growth.

The unfortunate substitution (fig. 91; 108, 2) of a Belgian form (which is *Ferestromatopora tyrganensis* Yavorsky) for the authentic type species of *Stromatopora*, *S. concentrica* Goldfuss (Nicholson, Mono, 1886, pl. 11, fig. 16, 18), which Lecompte also did in his Belgian Memoir (1952, pl. 63, fig. 2–4), can only lead to continuing confusion as to the character of the type species of *Stromatopora*. *Stromatopora hüpschii* (fig. 88) and "*Syringostroma*" *baccatum* Lecompte (fig. 106, 2) are the only real examples of thin sections of the genus *Stromatopora* given by Lecompte. *S. pachytexta* (fig. 109, 1) is not a *Stromatopora*, having long, thin, primary pillars not found in *Stromatopora*. The characteristics of type species are not adhered to. For example, the type of *Trupetostroma* (fig. 107, 1a) shows superposed pillars and galleries (chambers), but Lecompte's *T. ruedemanni* (fig. 98, 3) has neither, and is close to *Ferestromatopora krupennikovi* Yavorsky. *Clathrodictyon* here includes the typical forms without laminae (fig. 97) and forms with laminae (fig. 105, 3) which belong to the genus *Anostylostroma* Parks, not mentioned by Lecompte. It is most unlikely that *Stromatopora douvillei* (p. F142) from the Mesozoic, belongs to *Amphipora*, lacking axial canal and marginal vesicles.

The following points can be made concerning Lecompte's classification:

1. The bases of classification are vague and not adhered to strictly. There is no definite statement of what is and what is not important in classification, nor sufficient indication of the relative value of the various structures in classification. Great difficulty will be experienced in trying to assign an unidentified specimen to its correct family and genus.

2. Too much emphasis is placed on the presence or lack of astrorhizae, a specific character at best, perhaps only a sexual character.

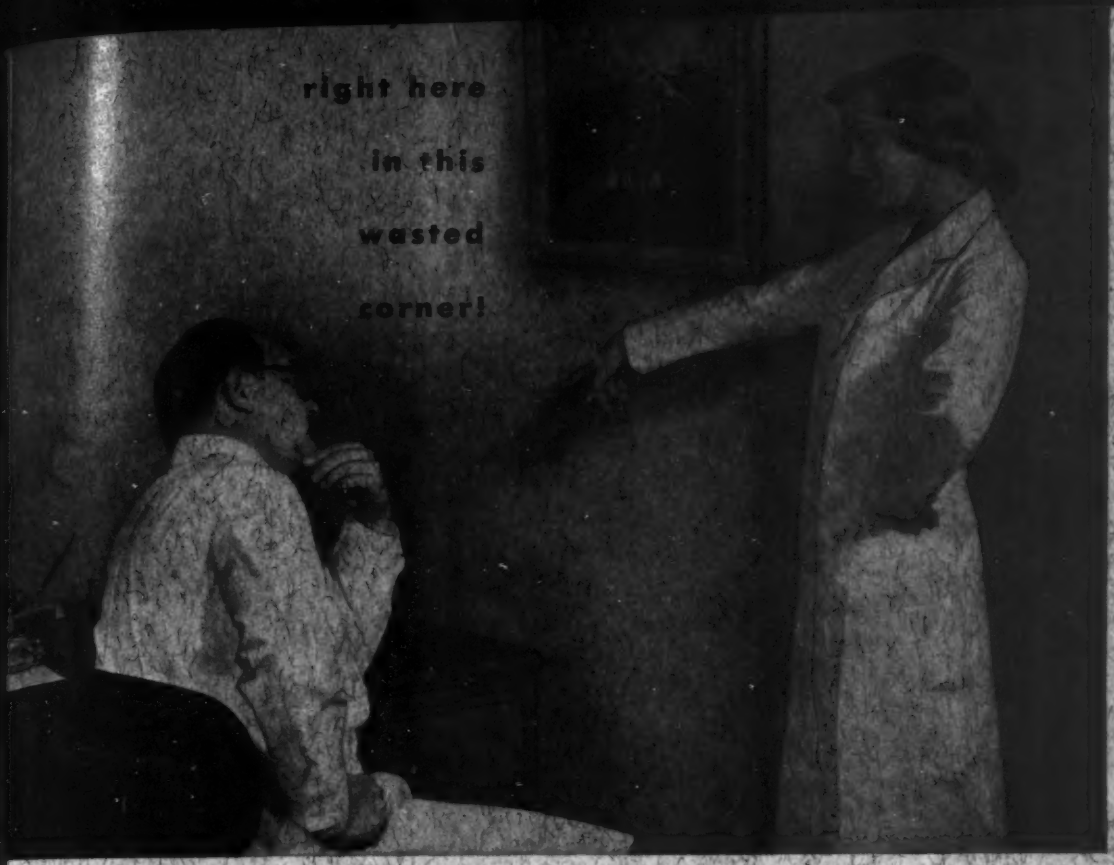
3. Not enough attention is given to tissue structure, nor enough weight to its value in classification.

4. Lecompte apparently does not clearly see the comparison of similar structures, but compares unrelated structures, with the result that several genera have been placed closely together in the classification which have little in common other than being stromatoporoids or in some cases in being hydroids.

5. Consideration is not given to geologic occurrence in the classification. The incongruity of interspersing genera of Mesozoic Sphaeractinoidea among the families of Lower and Middle Paleozoic Stromatoporoidea would be as incongruous as placing the Mesozoic hexaseptate corals in the Lower and Middle Paleozoic tetraseptate coral families.

The paper under consideration is likely to add more to the confusion than to the clarification of an important but difficult group of fossil organisms.

JOSEPH ST. JEAN, JR.
Geology Department
Trinity College
Hartford, Connecticut



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